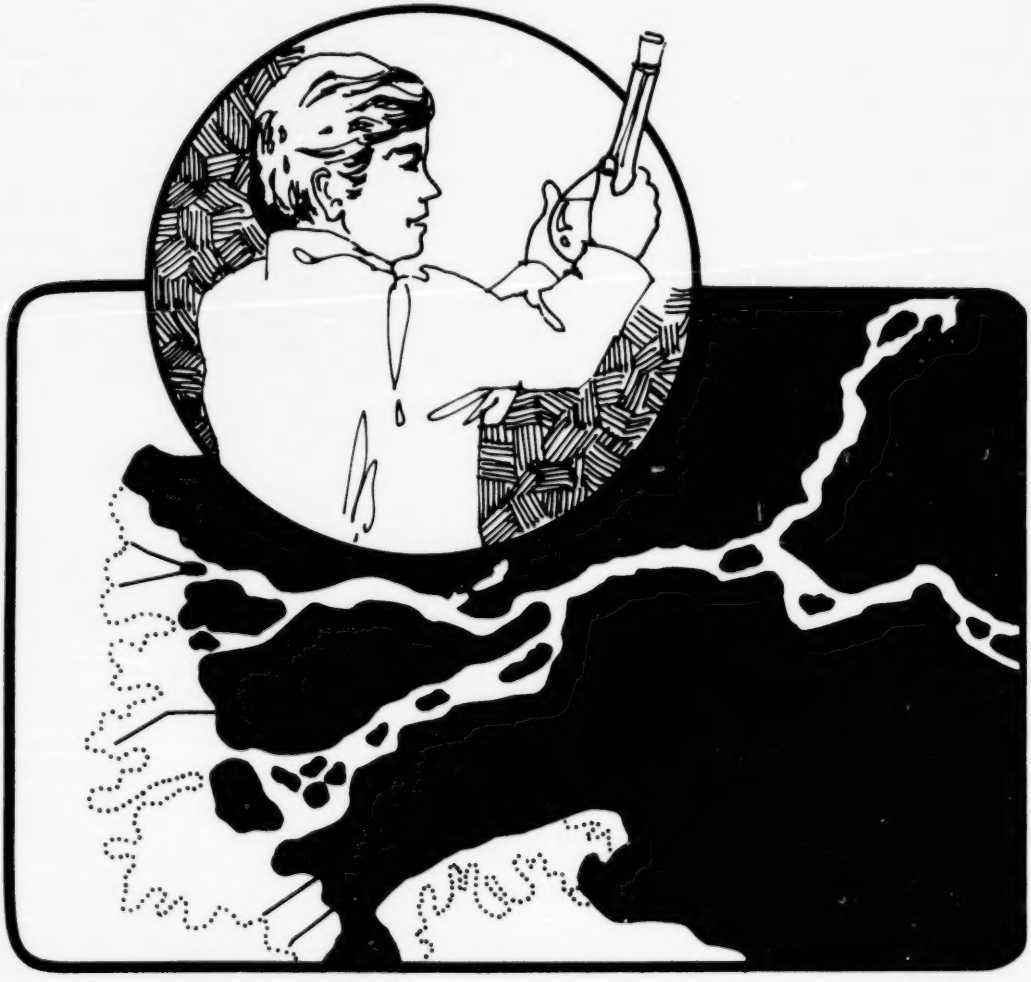
Fraser River Estuary Study
Water Quality

Boundary Bay



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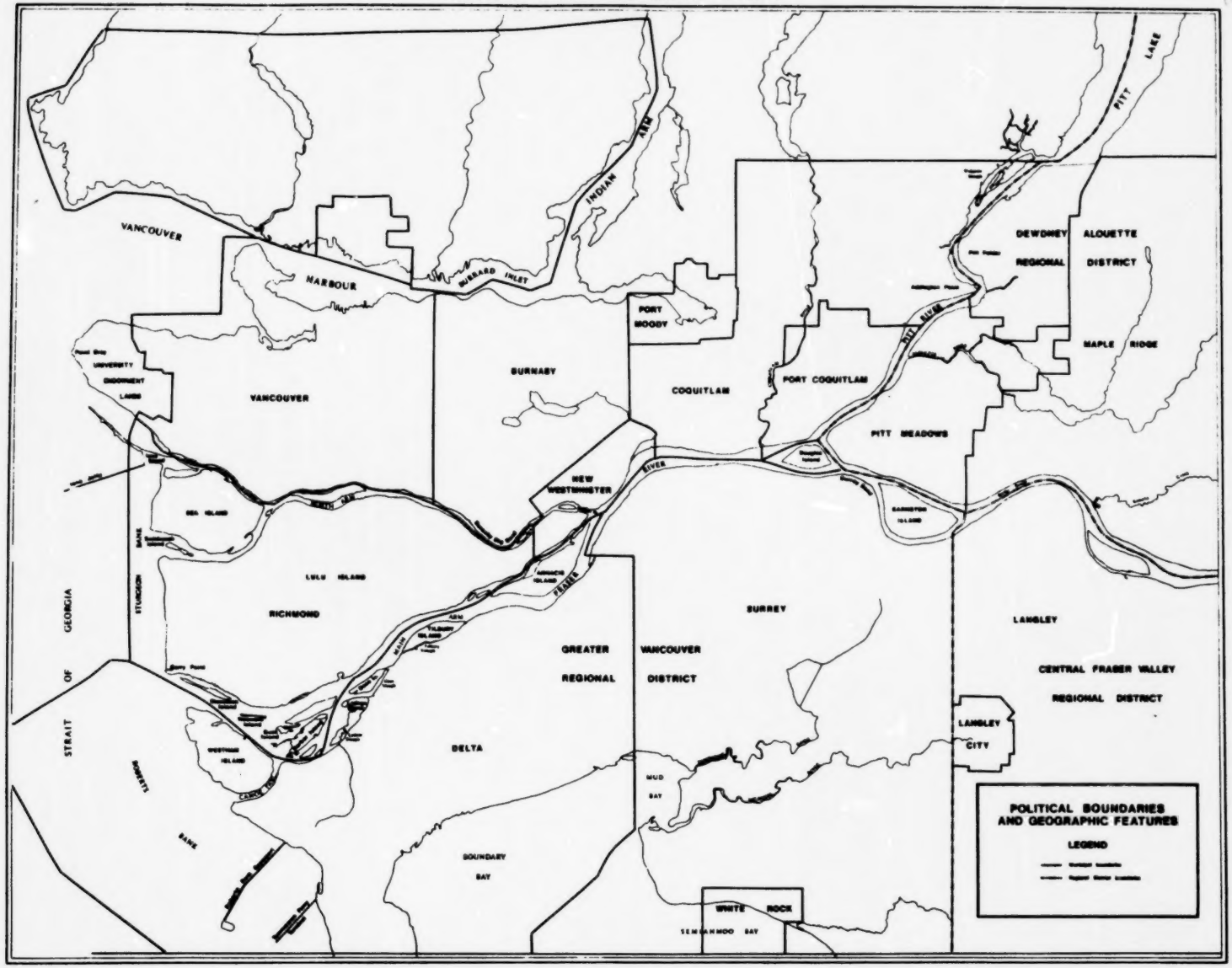

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Water Quality

Boundary Bay

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ABSTRACT

This report examines the water quality of Boundary Bay and its tributaries for the period 1972 to 1979.

The water quality of Boundary Bay is generally uniform throughout, except along its shorelines, where the impact of agricultural runoff was noted in bacteriological water quality. It is recommended that bacteriological monitoring of waters discharged from the land drainage pump stations be undertaken.

The Boundary Bay area remains closed to shellfish harvesting due to coliform contamination, although beach areas are safe for swimming. The chemical water quality, as determined from median values, generally meets criteria suggested for the propagation and maintenance of marine life. This water quality should be maintained, and if possible improved upon in order to protect the high biological productivity of the Bay.

Fish kills have occurred in the Nicomekl, Serpentine, and Campbell Rivers. Pesticide residues and low dissolved oxygen values are the main apparent cause. A study is needed to recommend methods of resolving the recurring fish kill problems. Part of the study should be assessments of present pesticide utilization, and of the safeguards needed to prevent toxic levels of pesticides entering waterways.

Ammonia toxicity was calculated not to be a potential problem in the Campbell River, although it could become a problem under certain conditions in the Nicomekl and Serpentine Rivers.

The chemical water quality of Boundary Bay does not appear to have been altered by the input of flows from the main tributaries. However, sediment and tissue analyses have not been performed on samples from Boundary Bay. These long term programs are required to monitor any build-up of contaminants from the tributaries or other sources.

PREFACE

The Fraser River Estuary Study was set up by the Federal and Provincial Governments to develop a management plan for the area.

The area under study is the Fraser River downstream from Kanaka Creek to Roberts Bank and Sturgeon Bank. The Banks are included between Point Grey and the U.S. Border. Boundary Bay and Semiahmoo Bay are also included but Burrard Inlet is not in the study area.

The study examined land use, recreation, habitat and water quality, and reports were issued on each of these subjects.

Since the water quality report was preliminary, a more detailed analysis of the information was undertaken by members of the water quality work group. As a result, eleven background technical reports, of which this report is one, are being published. The background reports are entitled as follows:

- Municipal Effluents.
- Industrial Effluents.
- Storm Water Discharges.
- Impact of Landfills.
- Acute Toxicity of Effluents.
- Trace Organic Constituents in Discharges.
- Toxic Organic Contaminants.
- Water Chemistry; 1970-1978.
- Microbial Water Quality; 1970-1977.
- Aquatic Biota and Sediments.
- Boundary Bay.

Each of the background reports contains conclusions and recommendations based on the technical findings in the report. The recommendations do not necessarily reflect the policy of government agencies funding the work. Copies of these reports are available at all main branches of the public libraries in the lower mainland.

Five auxiliary reports are also being published in further support of the study. These cover the following subjects:

- Site registry of storm water outfalls.
- Dry weather storm sewer discharges.
- Data report on water chemistry.
- Survey of fecal coliforms in 1978.
- Survey of dissolved oxygen in 1978.

Copies of these reports are available from the Ministy of Environment, Parliament Buildings, Victoria, British Columbia.

To bring this work together the water quality work group has published a summary report. This document summarizes the background reports, analyzes their main findings and presents final recommendations. Some of the recommendations from the background reports may be omitted or modified in the summary report, due to the effect of integrating conclusions on related topics. Copies of the summary report are in public libraries, and extra copies are available to interested parties from the Ministry of Environment in Victoria.

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1. INTRODUCTION

Boundary Bay is located approximately 14 kilometres south of the Main Arm of the Fraser River, and southeast of the active sediment fronts of Roberts and Sturgeon Banks. Boundary Bay was divided in two areas for the purposes of this report, as shown in Figure 1. Boundary Bay East includes the Town of White Rock, Ocean Park, Crescent Beach, Mud Bay, Semiahmoo Bay and the mouths of the Campbell, Nicomekl, and Serpentine Rivers. Boundary Bay West includes the Beach Grove and Point Roberts areas. The International Border runs across the southern opening of Boundary Bay.

The water chemistry and bacteriological quality of Boundary Bay are considered separately from the Fraser River since the Bay is hydrologically independent from the river, has its own watershed, and contains few industries. The data base used covers the period 1972 to 1979.

Boundary Bay has always supported an important fisheries resource. Prior to the closure of Boundary Bay for shellfish harvesting by the Provincial Department of Health, based upon surveys conducted by the Department of National Health and Welfare in 1962, the waters of Mud Bay, Boundary Bay, and Crescent Beach accounted for over 60% of the total yearly British Columbian oyster harvest[20]. The Bay continues to be a good source of Dungeness crabs. During 1979, 96 tonnes of crab was taken, as was 1 tonne of smelt[21]. The Dungeness crab catch in 1978 had been 189 tonnes[22], up from the 90 tonnes caught during 1977[23].

2. DISCHARGES TO BOUNDARY BAY

Contaminants enter Boundary Bay either from direct discharges to the Bay, or via tributary streams. The major tributary streams entering Boundary Bay are the Nicomekl, Serpentine, and Campbell Rivers. Contaminants enter these tributary streams either from point sources such as effluents, or from non-point sources such as agricultural runoff.

Discharges from the Serpentine and Nicomekl rivers are seasonal as well as tide dependent, since water is held behind flood gates on the rivers during summer months for irrigation purposes. Significant discharges occur after rainy periods.

The foreshore of Boundary Bay is under the control of the Province of British Columbia. Since 1977, environmental impact statements have been required for all development proposals on the foreshores and submerged lands of Semiahmoo Bay and Boundary Bay[9].

2.1 Domestic Sewage Discharges

Domestic sewage which entered the Boundary Bay area originated from sewage treatment plants, sewage pump station overflows, and septic tanks.

2.1.1 White Rock Sewage Treatment Plant (PE 48)

The City of White Rock operated a secondary sewage treatment plant (STP) that discharged into the mouth of the Campbell River, between 1962 and 1977 (Figure 1). In July 1977, the untreated sewage which had been treated at this treatment plant was diverted to a Greater Vancouver Sewage and Drainage District (GVS & DD) trunk sewage collection line for treatment at the Annacis STP.

The plant discharged treated sewage prior to July 1977 at an average annual summer flow rate of 2 900 m^3/d. During the winter, the average flow rate was approximately 12 000 m^3/d. Flows in excess of 9 100 m^3/d were bypassed to Boundary Bay, untreated. The plant processes included comminution, settling (and sludge removal), an activated sludge process, settling and flow recycle, and post-chlorination from April through October. The plant processed domestic sewage only, with no input from industry.

Monitoring data on effluent quality from the plant were collected by the Pollution Control Branch (now Waste Management Branch), and a summary of these data is included as Table 1. The data indicate that between 1972 and 1976, the median five-day biochemical oxygen demand (BOD_5) was 37 mg/L and the median suspended solids concentration was 127 mg/L. These results were based upon limited data. However, the median BOD_5 value met the Pollution Control Board level "BB" objective of 60 mg/L. The three fecal coliform values ranged from 1 300 MPN/100 mL to 20 000 MPN/100 mL.

Extensive analyses carried out by the Environmental Protection Service (EPS) during 1971 and 1972 indicated that concentrations of chromium, iron, nickel, cadmium, and lead were not detectable[2]. Concentrations of copper and zinc were either not detectable or were less than 0.05 mg/L[2]. A few higher values are reported in the provincial data in Table 1. All metals, except iron, were so low in the plant influent that little change in concentrations was apparent when influent and effluent data were compared.

The EPS reported the results of twenty-one static bioassays. The tests were performed between March 1971 and June 1972, using coho salmon. Both the influent and effluent was found to be either non-toxic or only slightly toxic. These results may have been due to the absence of industrial input to the plant. However, the authors noted that due to high fish densities (greater than 1 gram per litre) used in all but one test, the toxicity of the samples may have been underestimated[2].

2.1.2 Sewage Pump Stations

The location of six sewage pump stations is indicated in Figure 2. Sewage pump stations are used in sections of the sewage collection system where sewage cannot flow by gravity.

The three sewage pump stations in White Rock (No. 2, No. 3, and No. 4) pump sewage to the GVS & DD pump station (No. 1). If the GVS & DD pump station and backup equipment fail, sewage backs up in the collection system and enters a stormwater manhole approximately 400 metres east of the pump station. Ferguson and Kay have reported numerous instances of the four White Rock pump stations discharging to Semiahmoo Bay during November and December of 1977. They also reported three discharges through the abandoned White Rock STP outfall into the Campbell River[3].

The Municipality of Surrey operates two pump stations, one of which can discharge to Boundary Bay (Figure 2). Ferguson and Kay reported that there were no indications of sewage overflows at either of these pump stations[3].

2.1.3 Septic Tanks

Areas which did not have centralized sewage collection systems disposed of their sewage in septic tanks. This was true of the Douglas Border Crossing until 1975, which discharged the sewage with stormwater. Between 1975 and 1978, the septic tanks were used as holding tanks, and the sewage was trucked to the Iona STP. However, quantities of sewage continued to enter the Bay until late 1978, when the facility at the border was connected to the GVS & DD trunk system[3].

The Semiahmoo Indian Band reserve is unsewered, and Ferguson and Kay noted possible septic tank seepage near three residences[3].

2.2 Land Pump Stations

Pump stations are utilized at five locations to aid in land drainage projects. The pump stations are required to lift drainage water, which accumulated in ditches, over the dykes and into the Bay. The locations of such stations, labelled P-1 to P-5, are indicated in Figure 3.

The five land drainage pump stations were sampled during November and December of 1977. These pump stations drain predominantly agricultural-type land, as seen in Figure 9. The bacteriological results are included in Figure 3. These results indicate that the lowest total and fecal coliform values occurred at P-2 (median values 270 MPN/100 mL and 33 MPN/100 mL, respectively) and the highest at P-3 (median values 5 400 MPN/100 mL and 140 MPN/100 mL, respectively).

Samples were analyzed for nutrients at both P-1 and P-5 by Ferguson and Kay[3]. They reported the following median values: ortho phosphate (P), 0.17 mg/L; total phosphorus, 0.25 mg/L; nitrite, 0.018 mg/L; nitrate, 1.4 mg/L; and ammonia, 0.44 mg/L[3].

Samples of land drainage water have also been collected to determine 96-hour LC_{50} values from static bioassays, using rainbow trout as the test species. Seven tests

were performed on the drainage water from the five pump stations. These tests indicated that the waters were non-acutely toxic[3].

Sediments adjacent to the outfalls from the drainage pump stations were analyzed for hexachlorobenzene and the polychlorinated biphenyl, Aroclor 1 260[3]. All samples analyzed had less than one part per billion (ppb) of hexachlorobenzene. However, significant concentrations of Aroclor 1 260 were found at P-3 and P-4. The concentrations at a distance of 4.6 metres west of the outfall were 1 200 ppb at P-3 and 3 800 ppb at P-4[3], compared to 31 ppb at background stations. Subsequent sampling at these locations did not reveal high levels of polychlorinated biphenyls[13].

2.3 Industrial Effluents

Swain[1] has described elsewhere the industrial effluents which are discharged directly to the Serpentine River, or its tributaries (Figure 10). The industries and their pollution control permit numbers are Associated Foundry (PE 1529), Gearmatic Company (PE 2361), Capital Plastics (PE 2645), Reliance Foundry (PE 2549), Stowe Woodward (PE 2624) and Ferro Enamels (PE 2208).

Associated Foundry melts scrap metal to produce plumbing pipe. The wastewater is treated by being passed through an oil separator and a series of catch basins. Pollution control permit PE 1529 restricts the pH to a range from 6.5 to 8.5, oil and grease to 15 mg/L, suspended solids to 30 mg/L, and flow to 19 m^3/d. Effluent characteristics gave the following ranges: pH, 4.6 to 11.4; suspended solids, 2.3 to 238 mg/L; oil and grease, 0.06 to 100 mg/L; and flow, 0 to 83 m^3/d[1].

Gearmatic Company Ltd. manufactures winches. The wastewater originates from water fountains, air compressors, a deburring machine, and a flame hardening unit. Pollution control permit PE 2361 restricts the flow to 29.6 m^3/d, at a maximum temperature of 24°C. Data obtained between 1974 and 1979 on effluent quality showed oil and grease concentrations as high as 15.5 mg/L, with a median value of 2.7 mg/L[1].

Capital Plastics is a film and flexible packaging manufacturing plant. It discharges wastewater which is made up of cooling water, and bleedoff from the polyethylene reclaim machine. The wastewater is treated in a sedimentation sump, and is restricted by pollution control permit PE 2645 to a flow of 54.6 m^3/d, at a temperature of

32.2°C. The pH of the effluent in the period 1975 to 1977 ranged from 6.3 to 6.8, while the suspended solids ranged from <1 to 5.6 mg/L[1].

Reliance Foundry discharges cooling water which has passed through closed jackets. Pollution control permit PE 2549 restricts the flow to 113.6 m^3/d at a temperature of 23.9°C. Data from the period 1974 to 1977 indicate that the temperature ranged from 1°C to 23°C. The flow during 1977 ranged from 14 to 109 m^3/d (median 62 m^3/d)[1].

Stowe Woodward discharged cooling water which has been used to cool the compressor and manufactured rubber rollers until 1976. At that time, the cooling water was discharged to the municipal sewage system. Pollution control permit PE 2624 restricted the flow to 227 m^3/d at a temperature of 21.1°C. The data indicate that the flow during 1975 ranged from 65.5 to 163.7 m^3/d, while the temperature ranged from 14°C to 22.8°C.

Ferro Enamel, a paint manufacturing company, discharges cooling water. The company is restricted by pollution control permit PE 2208 to a flow of 2 m^3/d at a maximum temperature of 26.7°C. No data were recorded for this operation[1].

2.4 Landfills

Atwater reviewed landfill sites in the study area, including four which operated before 1967 in the Boundary Bay watershed[19]. The location of the landfills are shown in Figure 12.

The Semiahmoo and 24th Avenue landfills were called "very small and old"[19]. The Elgin landfill covered an area of approximately 1.2 hectares. A 1979 inspection of the Elgin landfill indicated some "leachate seeps along the north boundary" and "pools in the area of the eastern boundary"[19]. No analytical information concerning refuse constituents or leachate compositions were available for any of these landfills.

The Bear Creek landfill received both municipal and commercial garbage, being bounded on the east by Bear Creek, and on the west by a Bear Creek tributary. Leachate from the site has been seen as seeping into Bear Creek along a 400 metre distance as recently as 1979[19]. Data reported by Atwater for samples taken in July

1970 and May 1971 upstream and downstream from the landfill, indicated no trend for copper or iron, the only two parameters measured in both years[19]. Based upon one set of data, values for chloride, zinc, barium, sodium, potassium, calcium, magnesium and dissolved solids increased downstream from the landfill; values for sulphate and ammonia decreased; while values for lead, aluminum, boron, chromium, and magnesium showed little or no increase. Sulphate, chloride, ammonia, zinc, and lead were measured in May 1971, while the other values were measured in July 1970.

Atwater cited Watkins who reported an abundance of coho fry upstream from the Bear Creek landfill and extending approximately 180 metres downstream into the fill area, as well as immediately downstream from the fill area during 1970[19].

2.5 Stormwater Discharges

A site registry of stormwater outfalls within the Fraser River study area has been prepared[4]. Stormwater outfalls to Boundary and Semiahmoo Bays are indicated in Figure 4. No data were collected from these twelve outfalls, except for one sample collected by EPS. It indicated that the stormwater had the following characteristics in 1977: pH, 7.6; ortho phosphate, 0.12 mg/L; total phosphorus, 0.49 mg/L; nitrite, 0.048 mg/L; nitrate, 2.7 mg/L; and ammonia, 0.78 mg/L[3].

2.6 Agricultural Runoff

Figure 9 indicates that areas surrounding most of Boundary Bay, as well as the Nicomekl, Serpentine, and Campbell Rivers are mostly zoned agricultural according to the Greater Vancouver Regional Plan of November, 1980. Most of these areas are presently used for agricultural purposes[14]. Section 2.2 discusses predominantly agricultural type land drainage which enters Boundary Bay via five land pump stations.

Data have been collected on more than one occasion at Border Feedlot on the Campbell River, due to fish kills suspected as having resulted from runoff from the operation. These results are included in Tables 11 and 12. They indicate a significant increase in values between sites upstream and downstream from the operation on an adjacent creek (Figure 11) for the following parameters: total organic carbon, ammonia, nitrate, nitrite, organic nitrogen, BOD_5, total phosphorus, ortho phosphate and total fixed solids. Coliform data were not reported, but would be expected to be high due to the

nature of the wastes generated at a feedlot.

2.7 Other Possible Influences

The City of Blaine in the State of Washington has discharged primary treated sewage into the mouth of Drayton Harbour (see Figure 1). The plant is restricted by its waste discharge permit as follows: flow, 1 700 m^3/d; monthly average fecal coliform, 700 per 100 mL; BOD_5 load, 20 kilograms per day (kg/d); and suspended solids load, 80 kg/d. The sewage is discharged through a 490 metre outfall to the mouth of Drayton Harbour.

A new secondary treatment plant utilizing a rotating biological contactor went into operation in Blaine in October 1980[5]. A rotating biological contactor consists of a series of discs on a horizontal shaft placed in a tank. Wastewater slowly flows through the tank, making contact with the discs which are submerged approximately forty percent. The discs on the shaft slowly rotate, making contact with a thin layer of wastewater which flows over the disc surface as the discs emerge from the tank, absorbing oxygen from the air. The fixed biomass film removes organic matter from the wastewater. Excess solids are sloughed from the discs during rotation, and are eventually removed in a clarifier.

The new plant discharges through a 790 metre outfall into Semiahmoo Bay, and is restricted by its waste discharge permit as follows: flow, 3 000 m^3/d; monthly average fecal coliform value, 200 MPN per 100 mL; BOD_5 load, 90 kg/d; and suspended solids load, 90 kg/d.

Tidal currents in the Boundary, Semiahmoo, and Mud Bays were depicted in Warren[9] and are reproduced in Figure 6. This pattern of currents indicates that sewage discharged from the new plant could be carried into Boundary Bay.

Four fish processing plants discharged screened effluent to Drayton Harbour. These plants recently began discharging wastes to the municipal sewerage system for treatment at the new secondary treatment plant[5]. The plants, in total, were limited to a discharge of 300 m^3/d to Drayton Harbour.

3. WATER QUALITY

3.1 Tributaries

3.1.1 Nicomekl River

The Nicomekl River enters Boundary Bay towards its northern tip. This river is generally surrounded along its length by agricultural land (Figure 9). Water quality sampling was carried out by the Province at several stations from 1975 to 1979. Station 1100003 (Figure 5) was chosen as being the most representative sampling station for the water quality of the Nicomekl River as it enters Boundary Bay. Stations downstream from 1100003 were influenced by tidal action in terms of saline intrusions. Station 1100003 was also affected by tidal action, until the tidal gates were repaired in late 1975. The data are summarized in Table 2.

Total solids values were high during the low precipitation period, presumably indicating a build-up of dissolved solids due to high evaporation rates during the peak irrigation season, with associated high dissolved solids in irrigation runoff. The median total solids concentration however was only 228 mg/L. The high total solids values were also reflected in values for sulphate, sodium, potassium, magnesium, chloride, and calcium. Median values for these constituents were much less than the maximum recorded values.

Dissolved oxygen values ranged from 5.2 to 22.5 mg/L, with a median value of 10.3 mg/L. The tenth and ninetieth percentiles were 6.9 mg/L and 19.3 mg/L, respectively. This indicates that over 10% of the data were below 7.75 mg/L, the value proposed by Davis to provide a high safeguard for important freshwater salmonid populations[15]. Dissolved oxygen values are likely lowered due to small freshwater inputs, retention of water behind the flood gates for long periods of time, and high water temperatures which promote algal growths with resulting reductions in dissolved oxygen. Concentrations of oxygen which may be present in water naturally decrease with increasing temperatures.

Percentage saturation values were not calculated. However, low dissolved oxygen values together with pesticide use were implicated in a reported fish kill in the Nicomekl River in June 1969 (Table 3).

Ammonia values are reported as the sum of the dissociated (NH_4^+) and undissociated (NH_3) forms. In aqueous solutions, the two forms of ammonia are in equilibrium with each other. This equilibrium is mainly a function of pH, and to a lesser extent, salinity and temperature. The NH_3 form is predominantly toxic. Levels of NH_3 of 0.02 mg/L (0.016 mg/L expressed as N) are toxic to aquatic life[7]. Tables 4 and 5 indicate the total ammonia concentrations which have an NH_3 level of 0.02 mg/L at various pH and temperature values for salinities of 0 parts per thousand (ppt) and 20 ppt.

Concentrations of NH_3 increase with decreasing salinity or increasing temperature. A worst case situation is one which would not normally occur, but given a certain combination of circumstances, could occur. One such situation would involve the river temperature rising to 25°C with zero salinity. Assuming the historical median pH value of 7.8, the concentration of total ammonia which contained 0.02 mg/L of NH_3 would be 0.66 mg/L. This value of total ammonia has never been approached in the river system. However, the most alkaline conditions historically recorded (pH, 9.1) in the river can generate toxic ammonia conditions, at about 25°C, zero salinity and with total ammonia concentrations of about 0.05 mg/L, a value recorded historically over fifty percent of the time. However, temperature and salinity conditions required to produce toxic concentrations may not have occurred concurrently.

Data have been reported in Table 6 for days on which pH, salinity, temperature, and total ammonia values were determined concurrently. The data indicate that calculated NH_3 values did not reach 0.02 mg/L in the river.

Most elements had median values within receiving water criteria suggested by the EPA as suitable for aquatic life (Table 7). These included boron, cadmium, copper, iron, manganese, and mercury. The median concentrations of lead and zinc were slightly above the criteria for these metals which are based on the 96-hour LC_{50} concentrations for trout and salmon.

Bacteriological sampling utilizes coliforms as indicator organisms in the detection of pathogenic organisms in water[18]. Few bacteriological data were collected. These indicated a median total coliform value of 625 MPN/100 mL. No data for flows through the tidal gates have been recorded. Flow records for upstream stations have not been cited due to the distance of these stations from the tidal gates, the fact that the tidal gates do not permit continuous outflows of river water, and that the volumes of river

water withdrawn for irrigation purposes are unknown.

3.1.2 Serpentine River

The Serpentine River enters the southern portion of Mud Bay. Water quality sampling was carried out by the Province at several stations from 1974 to 1979. Station 1100034 (Figure 5) was chosen as being the most representative of water quality of the Serpentine River as it enters Mud Bay. Stations downstream from station 1100034 are influenced by tidal action. This station was also affected by tidal action until the tidal gates were repaired in late 1975. The monitoring data are summarized in Table 8.

Total solids values were high on occasion during the low precipitation period, presumably indicating a build-up of dissolved solids due to high dissolved solids levels in irrigation runoff, high evaporation rates, and small freshwater inputs. The median total solids value however was only 528 mg/L. The high total solids values were reflected in values for sulphate, sodium, potassium, magnesium, chloride, and calcium. Median values for these constituents were much less than the maximum recorded values.

Dissolved oxygen concentrations ranged from 2.5 mg/L to 18.3 mg/L (median 10.1 mg/L). The tenth and ninetieth percentiles were 5.2 mg/L and 14.5 mg/L, respectively. This indicates that over 10% of the data were below 7.75 mg/L, the value proposed by Davis to provide a high safeguard for important freshwater salmon populations[15]. Values less than 5.0 mg/L were recorded in September 1976 and August 1979. These values occurred during periods of high water temperatures and low river flows.

Percentage saturation values were not calculated. However, low dissolved oxygen values were implicated in reported fish kills in July 1973 and October 1980, as well as in the Bear Creek tributary in July 1972 (Table 3). Pesticides were implicated in one reported fish kill on the Serpentine River in September 1970.

Ammonia toxicity, and its relationship to pH, temperature, and salinity, has been discussed in Section 3.1.1. The pH in the Serpentine River has historically ranged from 6.2 to 8.7 (median 7.3). At this median pH, a temperature of 25°C, and a salinity of 0 ppt, a concentration of 2.0 mg/L of total ammonia results in a calculated NH_3 value of 0.02 mg/L. The total ammonia concentration in the river never approached the assumed value of 2.0 mg/L. The most alkaline conditions historically recorded in the river (pH,

8.7) at a salinity of 0 ppt and 25°C require a total ammonia concentration of only 0.093 mg/L to produce toxic ammonia conditions. The median concentration of total ammonia (0.098 mg/L) barely exceeded this worst case value. However, the required temperature and salinity conditions may not have occurred concurrently.

Data have been reported in Table 9 for days on which pH, salinity, temperature, and total ammonia values were determined concurrently. The data indicate that calculated NH_3 values of 0.02 mg/L were not reached in the river.

Several elements had median values lower than receiving water elements suggested by the EPA (Table 7) for the protection of freshwater aquatic life. These included boron, cadmium, copper, lead, and mercury. Median values for iron and manganese were approximately equal to the criteria, while zinc exceeded the criteria. This could indicate potential toxicity to more sensitive aquatic species during periods when these criteria are not being met.

Few bacteriological data were collected. They indicated a median total coliform value of 490 MPN/100 mL and a median fecal coliform value of 100 MPN/100 mL. No flow data have been recorded for flows through the tidal gates, and upstream flow data will not be referenced for the reasons cited in Section 3.1.1.

3.1.3 Campbell River

The Campbell River enters Semiahmoo Bay immediately north of the International Border. Water quality sampling was carried out by the Province at several stations between 1972 and 1979. Station 0300065 was chosen as the most representative for water quality of the Campbell River as it enters Semiahmoo Bay (Figure 5). The station was unaffected by discharges from the White Rock STP during its periods of operation. The monitoring data are summarized in Table 10.

The maximum recorded total solids value was 180 mg/L, which indicates that the station was either not affected by tidal action or that sampling was coincidentally synchronized with low tide conditions. This fact was also reflected in recorded values for sulphate, sodium, potassium, magnesium, chloride, and calcium.

Dissolved oxygen concentrations ranged from 8.1 mg/L to 13.5 mg/L (median 10.3 mg/L). These values exceed the 7.75 mg/L value deemed by Davis to provide a high safeguard for very important freshwater salmonid populations[15]. However, low dissolved oxygen levels were implicated in reported fish kills in September 1970 and October 1976 (Table 3). Pesticides were implicated in fish kills on the Campbell River in 1964 and 1970.

Ammonia toxicity, and its relationship to pH, temperature, and salinity, has been discussed in Section 3.1.1. The pH of the Campbell River has historically ranged from 6.7 to 8.0 (median 7.4). At this median pH, a temperature of 25°C, and a salinity of 0 ppt, a concentration of 1.58 mg/L of total ammonia would produce a calculated NH_3 value of 0.02 mg/L. The concentration of total ammonia in the river was always less than 1.58 mg/L. For the most alkaline conditions historically recorded, the total ammonia concentration required according to calculations to produce toxic conditions is lowered to 0.37 mg/L. This worst case value was never reached during the period of record.

Most elements measured had median values less than the receiving water criteria for aquatic life outlined by the EPA (Table 7). These metals included boron, cadmium, chromium, copper, iron, lead, manganese, and nickel. The median value for zinc, although low (0.005 mg/L), exceeded the criterion of 0.001 mg/L. This could indicate potential zinc toxicity to more sensitive aquatic species during periods when this criterion is not being met.

Few bacteriological data were collected. These data indicated a median total coliform value of 1 100 MPN/100 mL, and a median fecal coliform value of 790 MPN/100 mL.

The flow data for the Campbell River were recorded for the period 1961 to 1964 inclusive[6] (Table 13). These data indicate a mean annual flow of 0.94 cubic metres per second (m^3/s), a mean minimum monthly flow of 0.14 m^3/s in August, and a mean maximum monthly flow of 2.43 m^3/s in December.

The impact of the Border Feedlot operation on an adjacent stream (tributary of the Campbell River) has been discussed in Section 2.5. Of equal concern to the impact of the feedlot on the stream would be the impact of this stream on the Campbell River. Data included in Table 12 indicate that there was a slight rise in the concentrations of

total organic carbon, ammonia and BOD_5 on three occasions in 1973, downstream from the feedlot.

3.1.4 Discussion

It is not possible to speculate on the loading contributed by the tributary streams, since the Nicomekl River and the Serpentine River are dammed for irrigation and flood control purposes. Overflows from the dams occur during the winter and periods of high precipitation, when flows are in excess of irrigation requirements.

Dissolved oxygen values in the Serpentine and Nicomekl Rivers have at times been less than 7.75 mg/L, the value deemed by Davis to provide a high safeguard for important freshwater salmonid populations[15]. As well, low dissolved oxygen values have been implicated in reported fish kills on both rivers. Although measured dissolved oxygen values on the Campbell River have exceeded the 7.75 mg/L criterion, two reported fish kills were believed to have been associated with low dissolved oxygen values. Pesticides were implicated as the cause of fish kills on both the Serpentine and Campbell rivers.

Ammonia concentrations in both the Serpentine and Nicomekl Rivers have historically been recorded at levels which, under certain pH, salinity, and temperature conditions, could prove to be toxic. Ammonia concentrations in the Campbell River have historically been recorded at levels which were calculated as not being toxic.

Values for zinc were recorded in all three rivers at concentrations which exceeded the most sensitive criterion suggested by the EPA as a level suitable for aquatic life. This may indicate potential zinc toxicity to more sensitive aquatic species during periods when the criterion is not met. Median lead concentrations in the Nicomekl River also exceeded the criterion for the protection of more sensitive aquatic species.

Few bacteriological data were recorded in any of the rivers. Those data collected generally indicated total coliform values of up to 1 000 MPN/100 mL, and fecal coliform values of up to 800 MPN/100 mL.

The three rivers are bordered by agricultural land. The amount of bacteriological contamination which originates from agricultural runoff depends upon several factors.

These include the type of fertilizers utilized (if of animal origin), crop cover, soil type, and in the case of grazing, animal density and the type and weight of animals. The influence of Border Feedlot (the only operation with appreciable quantities of monitoring data) on the coliform values in the Campbell River, has not been investigated. Adequate sampling of drainage from the land drainage pump stations has not been performed to characterize the waste and its effect in the Bay.

The water quality of the three rivers is thus generally not good at certain times. This is demonstrated by dissolved oxygen depressions which appear to be a frequent occurrence; ammonia concentrations in the Nicomekl and Serpentine Rivers which could be a problem under certain conditions; zinc concentrations which have exceeded the EPA criterion for the protection of sensitive aquatic species in all three rivers at different times; and lead values in the Nicomekl River which have on occasion exceeded the EPA criterion.

3.2 Boundary Bay

The Boundary Bay data were from two existing Provincial sampling stations (see Figure 5), one in the eastern portion of Boundary Bay (station 0300071) and one in the western portion (station 0300070). The data for station 0300071 are presented in Table 14, while the data for station 0300070 are presented in Table 15. Bacteriological data for beaches, collected by several agencies, are summarized in Table 16.

The median values for all parameters measured at the two Boundary Bay stations were nearly identical, suggesting a constant water quality throughout much of the Bay. However, maximum values for total and fecal coliform were higher in the eastern portion of the Bay, and maximum values for copper, lead, mercury, and zinc were higher in the western portion of the Bay.

Figure 6 shows the general direction of surface and tidal currents in the Bay, as interpreted by Warren[9]. The pattern of tidal currents indicates that Drayton Harbour (and any sewage discharged thereto) is flushed, with the counter-clockwise currents in Semiahmoo Bay potentially carrying some of this sewage into Boundary Bay. Mud Bay and a large portion of Boundary Bay are poorly flushed.

It is possible that the higher maximum coliform values in the eastern portion

of Boundary Bay were caused by the sources from the United States, the Campbell River, sewage pump stations in White Rock and, before 1978, the White Rock STP. However, data from EPS surveys have indicated that sources from the United States have not contributed to high coliform levels in Semiahmoo or Boundary Bay[17]. The alternating tidal currents in the Mud Bay area make any bacteriological load carried by the Nicomekl or Serpentine rivers important in this regard.

The bacteriological water quality of the Bay was judged by the EPS to be unacceptable for molluscan shellfish harvesting in surveys as recent as 1977[3]. The Canadian Shellfish Safety Program criteria for shellfish harvesting waters, also used by the United States Food and Drug Administration, are that the "median fecal coliform bacterial concentration should not exceed 14 MPN/100 mL with not more than 10 percent of samples exceeding 43 MPN/100 mL".

Data collected by the EPS were of the same order of magnitude as values reported in Table 15 for White Rock. The values reported by the EPS for Crescent Beach were in a narrower range but had higher median values. The EPS values for Beach Grove were approximately the same as those values reported in Table 16, although the EPS reported a wider range of values and a higher mean value at Boundary Bay, than are reported in Table 16.

The cleansing time to remove bacteriological contamination in shellfish has been conservatively estimated at fourteen days[11]. Any improvements in bacteriological water quality in the Bay would therefore soon be reflected in the bacteriological content of the shellfish.

The British Columbia Ministry of Health has adopted the United States EPA criteria for bacteriological water quality for contact recreation[7] [8]. These criteria state that "based upon a minimum of five samples taken over a 30-day period, the fecal coliform bacterial level should not exceed a log mean of 200 per 100 mL, nor should more than 10 percent of the total samples taken during any 30-day period exceed 400 per 100 mL".

There are four beach areas in which bacteriological samples have been collected by the Ministry of Health and the Greater Vancouver Regional District (GVRD). Actual sites are numbered from 313 to 381, and are shown in Figure 5. The data in Table 16 indicate that all median fecal coliform values were less than 100 MPN/100 mL. None

of these beach areas have been closed for swimming (Figure 5).

Relevant water quality criteria for the marine environment, drawn from Clark[8], are summarized in Table 17. The median values reported for stations 0300070 and 0300071 were compared to the listed criteria. Generally, the most stringent criteria were met. However, median values for cadmium, iron, and phosphorus were slightly above the most stringent criteria.

The maximum values in Boundary Bay East and West exceeded the most stringent criteria. These values included those for cadmium, iron, ammonia, phosphorus, and zinc. In addition, maximum recorded values in Boundary Bay West for copper, lead, mercury, and nickel exceeded the most stringent criteria. This may indicate that potential toxicity may exist to more sensitive aquatic species during periods when the criteria are not met, although there is no biological evidence that this occurs. Higher values in Boundary Bay East may be related to agricultural runoff.

Another report of the Fraser River Estuary Study has discussed the fish habitat of Boundary Bay[10]. No data are available for the species of fish present in Boundary Bay since no systematic sampling of fish has been conducted[10].

3.3 Overview of Water Quality

Although it is not possible to determine accurately the loadings from the tributary streams and the effect that these loadings have had on the water quality of Boundary Bay, a comparison of the median concentrations in the streams to the concentrations in the water column in Boundary Bay can be made.

Certain parameters were found at higher median values in all three main tributary streams than in Boundary Bay. These included iron, manganese, nitrogen, zinc, and total and fecal coliform. Median values of copper and lead in the Serpentine and Nicomekl Rivers exceeded the median values of those parameters in Boundary Bay. Phosphorus was at a higher value in the Nicomekl River. The effect of tidal action in flushing the Boundary Bay area is not known.

The median values for iron, manganese, nitrogen, zinc, total and fecal coliform, copper, lead, and phosphorus at stations 0300070 and 0300071 were plotted for

the years 1972-1979 in Figures 7 and 8 to determine any noticeable increase in these parameters in the water column. The information in Figure 7 indicates that there was no apparent appreciable trend of increasing values with time for any parameter throughout the period of record, except possibly for iron. This pattern was not noted in the data for Boundary Bay West (Figure 8). Analyses have not been carried out to determine whether values are increasing in sediments and tissues.

Although it may be more valuable to plot the tenth and ninetieth percentile values for total and fecal coliform (since much of the bacteriological contamination may be related to agricultural runoff), the low number of values recorded yearly did not permit these percentiles to be calculated.

4. SAMPLING PROGRAMS

The EPS conducts bacteriological and sanitary surveys of areas where shellfish are harvested both commercially and recreationally. These surveys assess the bacteriological quality of the shellfish growing waters and determine the location and impact of sources of fecal and industrial contamination to the growing waters. Generally, areas which are closed to shellfish harvesting are surveyed approximately every ten years, unless changes have occurred which could lead to an improved bacteriological water quality[12]. The EPS is not considering doing further sampling until improvements are made in agricultural practices which would reduce bacteriological contamination[13].

The Ministry of Health conducts bacteriological surveys at beach areas on a weekly basis during the summer recreation period. The Waste Management Branch regularly samples Boundary Bay, as well as the Nicomekl, Serpentine, and Campbell Rivers.

Pesticide residues in sediments have not been measured along the tributaries, behind the tidal gates, or in the Bay itself. Such measurements are important in view of the concentration of agriculture within the watershed area.

5. CONCLUSIONS AND RECOMMENDATIONS

There is generally a consistent water quality throughout Boundary Bay, although relatively higher values have been recorded in the Western portion of the Bay for copper, lead, mercury, and zinc, and in the Eastern portion and adjacent to the shoreline for total and fecal coliform. It is suspected that higher bacteriological values in the Eastern portion of the Bay and adjacent to the shoreline may be related to agricultural runoff.

Median values of most parameters measured in Boundary Bay receiving waters usually met the most stringent criteria applicable to the marine environment except for cadmium, iron, and phosphorus. In addition to these parameters, maximum recorded water quality values exceeded criteria for ammonia, zinc, lead, nickel, and mercury. At times when the most stringent criteria are not met, potential toxicity problems may exist for the most sensitive aquatic species, although no direct biological evidence has been found.

The bacteriological water quality of most of Boundary Bay is generally good, although localized high values continue to occur. It is believed that these values are related to the agricultural use of lands in much of the Boundary Bay watershed. These high values preclude taking shellfish from the area for human consumption. Beach areas have acceptable water quality for contact recreation, and have never been closed to the public. Existing monitoring programs carried out by the Ministry of Health should be maintained. Additional bacteriological monitoring of waters discharged from land drainage pump stations should be undertaken. As well, steps should be taken, if practical, to reduce the bacteriological input from agricultural lands.

Sediments adjacent to the outfalls from the land drainage pump stations contained significant polychlorinated biphenyl concentrations on one occasion. Further testing of these sediments for the presence of polychlorinated biphenyls is required. As well, sampling of sediments for the presence of pesticide residues should be undertaken in the tributaries and Boundary Bay.

Although loadings to the Boundary Bay area from the Serpentine and Nicomekl rivers could not be calculated, higher values in the rivers than in the Bay for copper, iron,

lead, manganese, nitrogen, phosphorus, and zinc, have not had a significant impact on the quality of the Bay since 1972. The water quality of the Campbell River is generally better than that of either the Serpentine or Nicomekl rivers, possibly due to less agricultural land adjacent to the Campbell River.

Low dissolved oxygen levels and runoff carrying pesticide residues, have been implicated as having caused fish kills along the Campbell, Nicomekl, and Serpentine rivers, as well as in tributaries thereto. Studies should be undertaken to recommend methods to resolve the recurring fish kill problems. These studies should assess present methods of pesticide application, and whether additional safeguards in pesticide application are required to prevent their intrusion into waterways at toxic concentrations.

In view of the large natural habitat and high biological productivity of Boundary Bay, the high fisheries capabilities of its tributaries and its high recreational use, the water quality of Boundary Bay and its tributaries should be maintained in the short term, and if possible improved in the long term.

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21) Government of Canada; Department of Fisheries and Oceans; Economic and Statistic Services and Fisheries Management; British Columbia Catch Statistics; 1979.

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23) Government of Canada; Department of Fisheries and Oceans; Economic And Statistic Services and Fisheries Management; British Columbia Catch Statistics; 1977.

FIGURE 1
BOUNDARY BAY

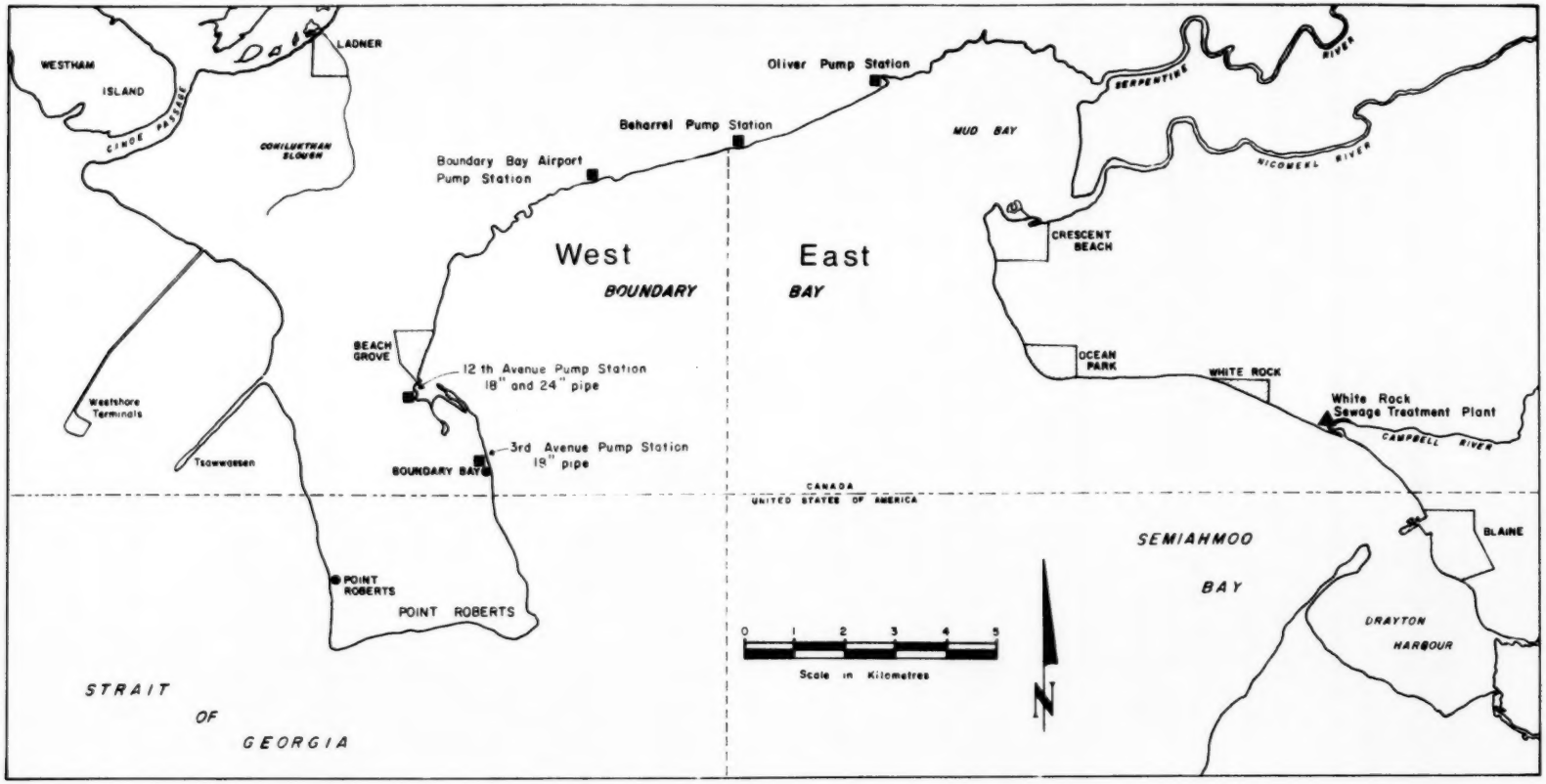


FIGURE 2

SEWAGE PUMP STATIONS

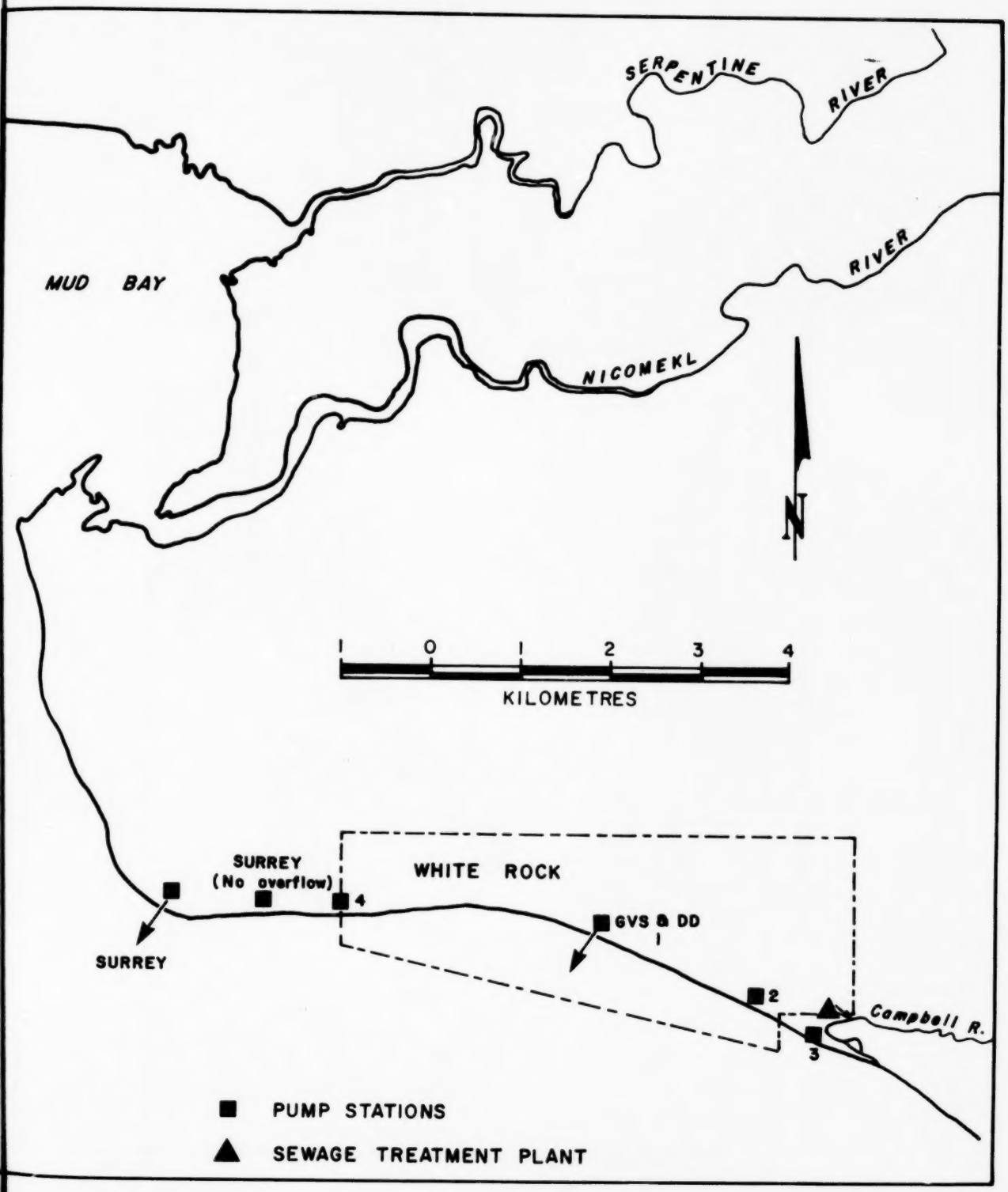


FIGURE 3

BACTERIOLOGICAL QUALITY AT LAND DRAINAGE PUMP STATIONS(3)

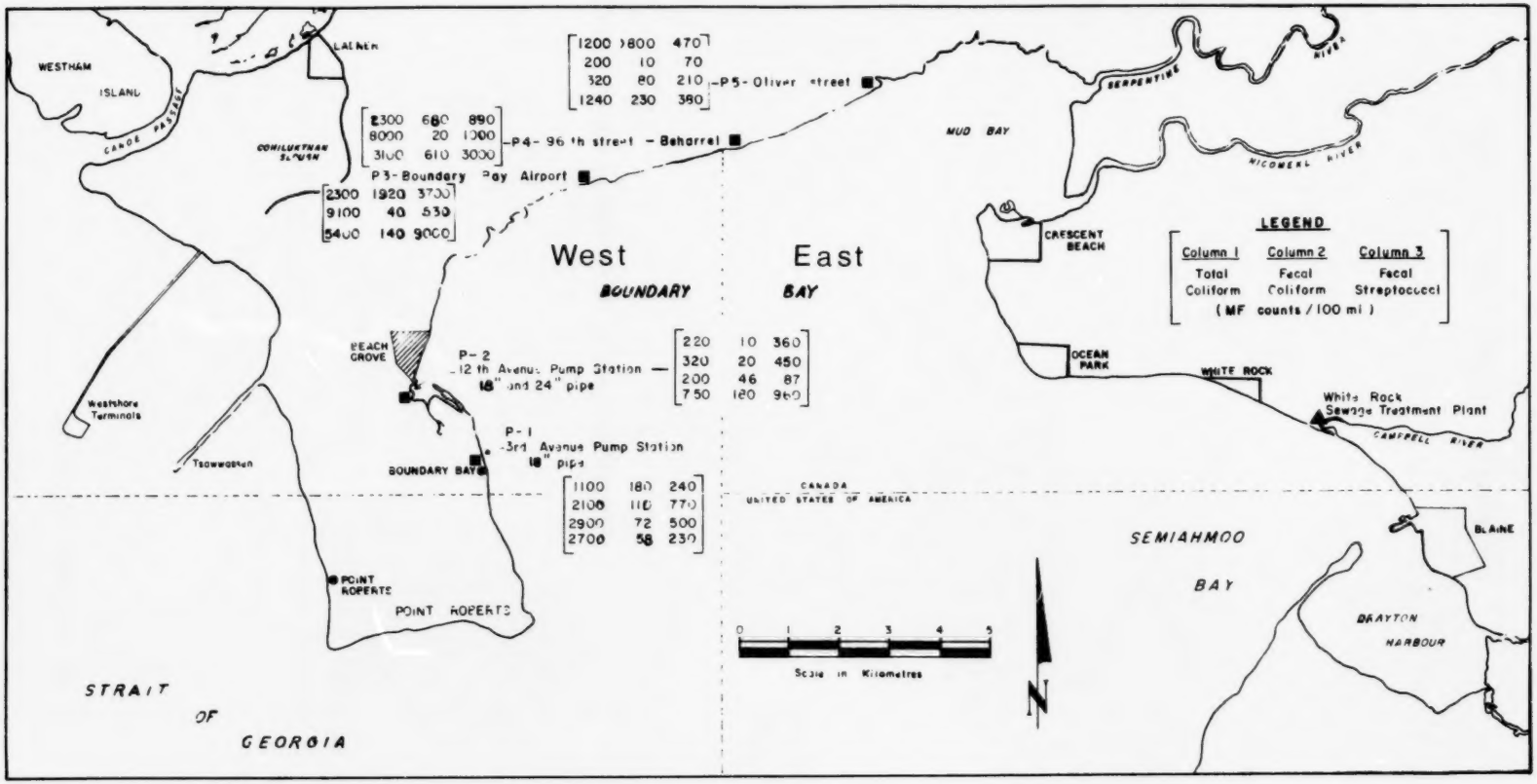


FIGURE 4

STORMWATER OUTFALLS[4]

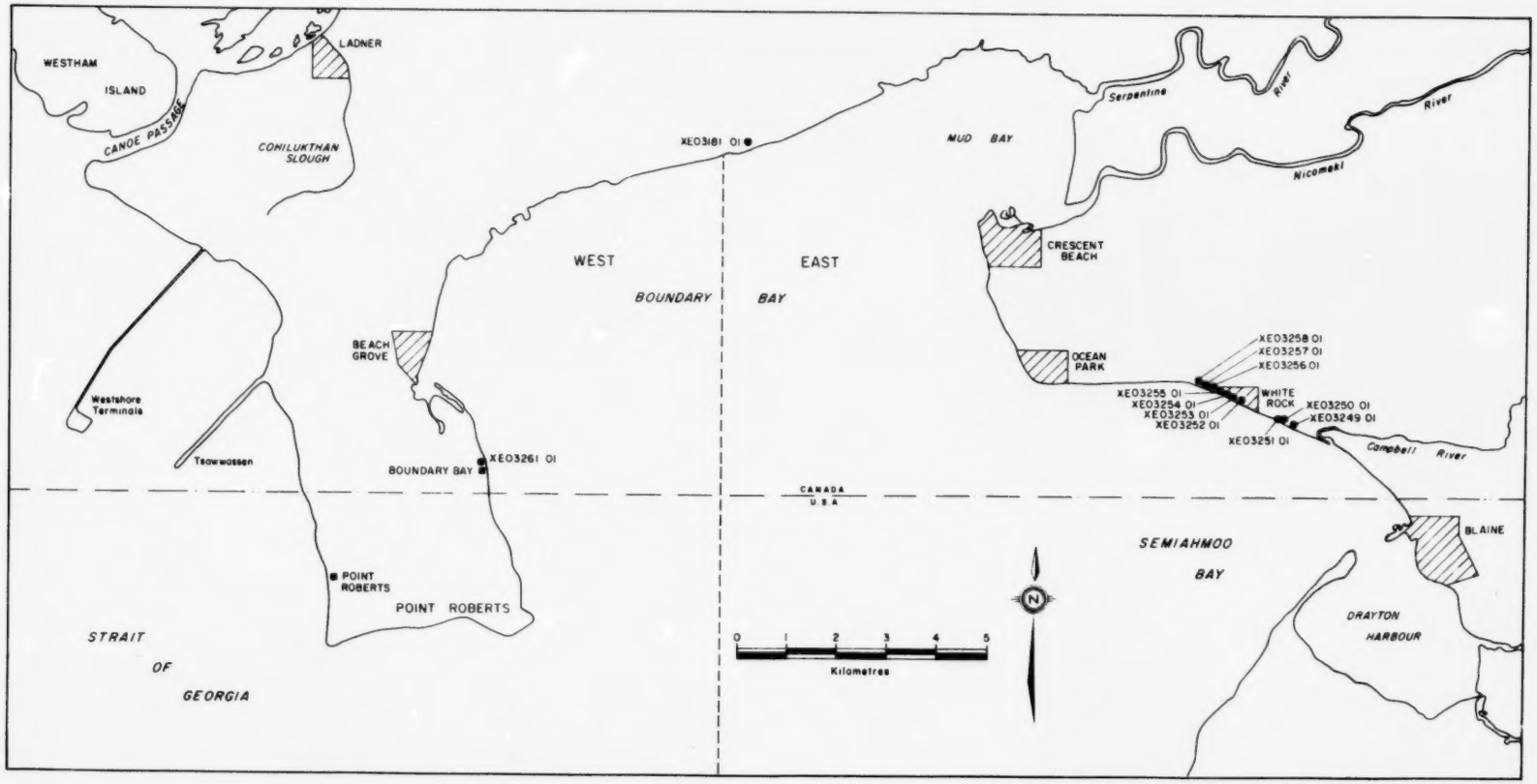


FIGURE 5
SAMPLING LOCATIONS

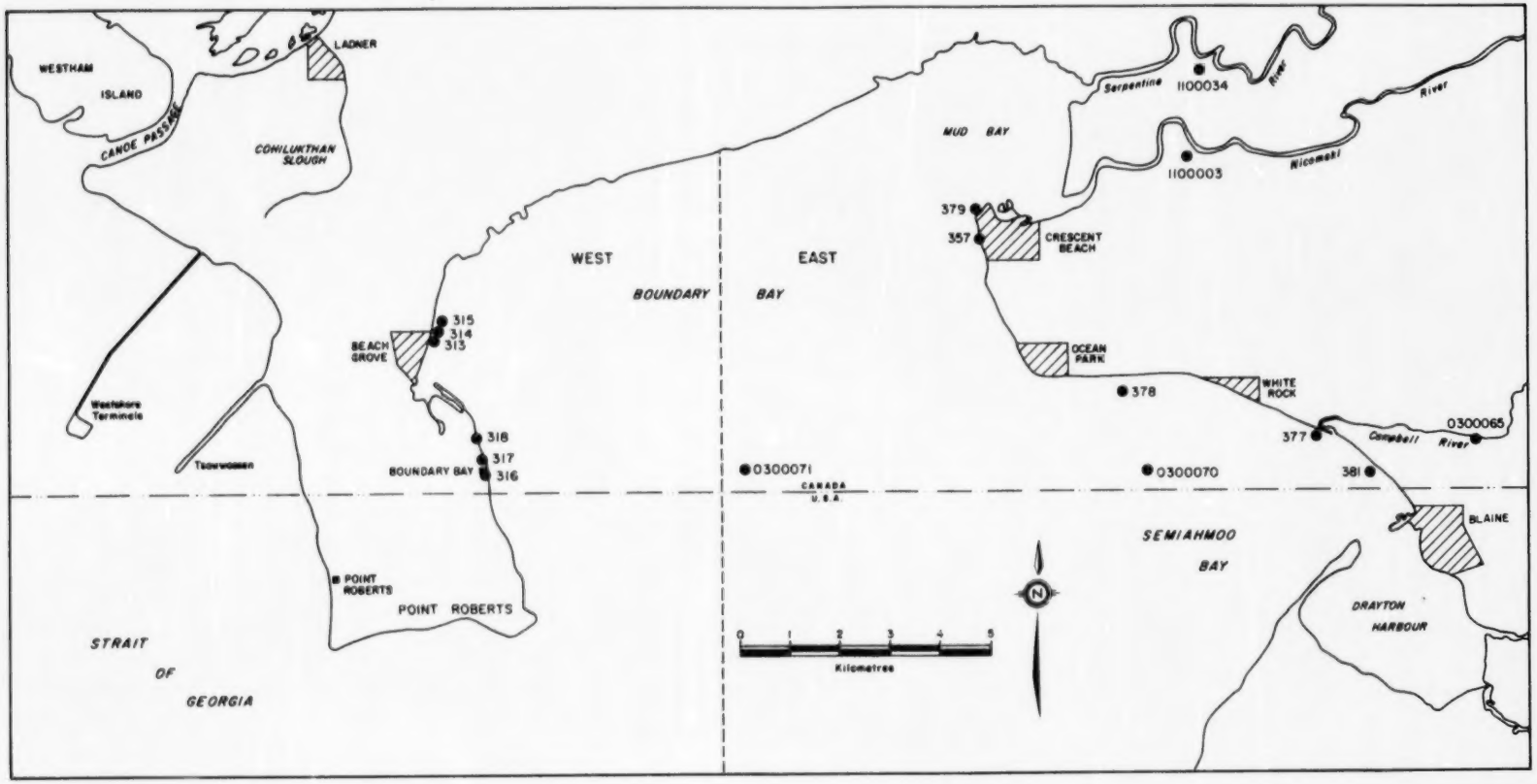
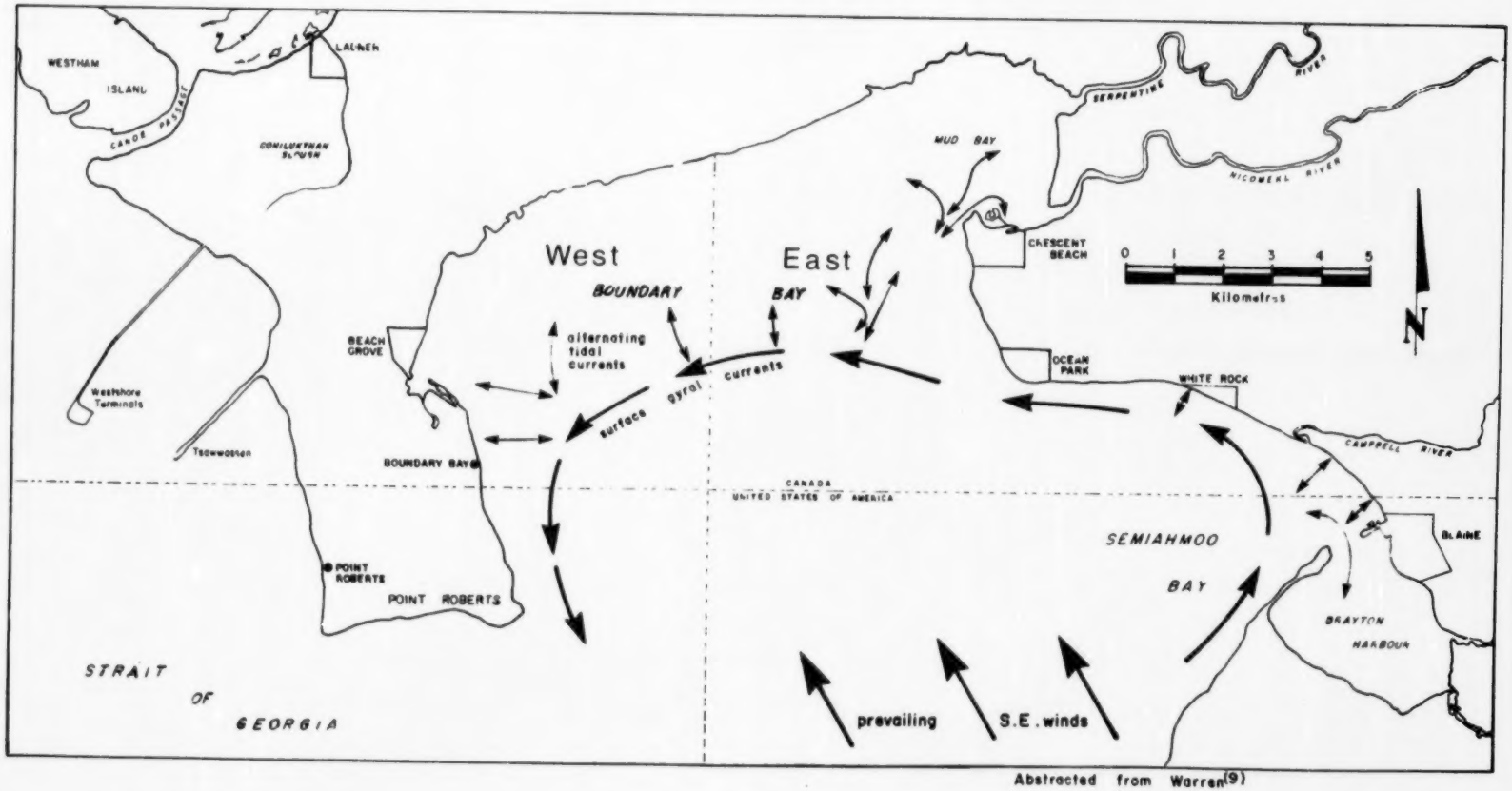


FIGURE 6 .
TIDAL CURRENTS



Abstracted from Warren[9]

FIGURE 7
YEARLY MEDIAN VALUE TRENDS
BOUNDARY BAY EAST
1972 - 1979

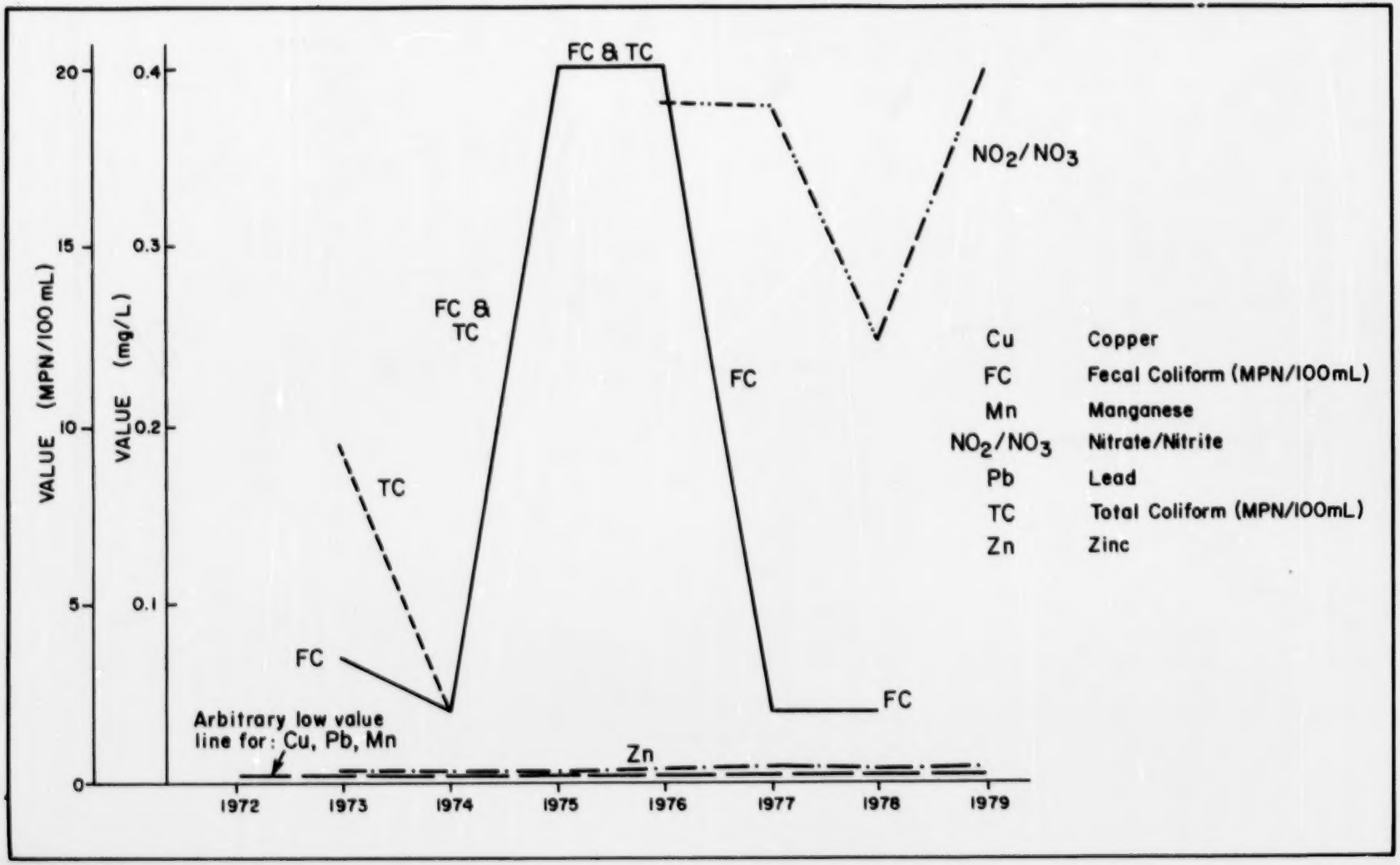


FIGURE 7a

YEARLY MEDIAN VALUE TRENDS

BOUNDARY BAY EAST

1972 - 1979

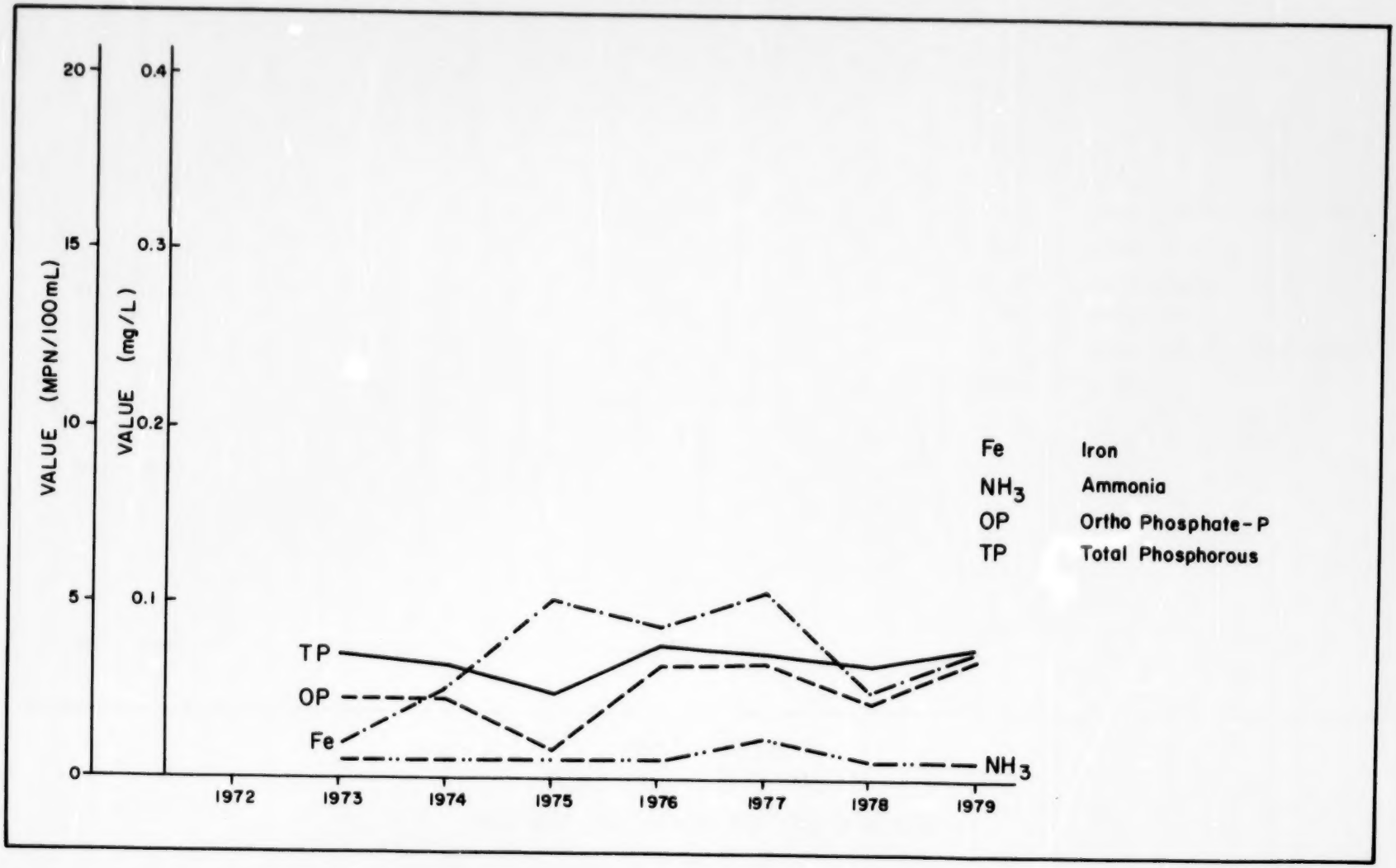


FIGURE 8
YEARLY MEDIAN VALUE TRENDS
BOUNDARY BAY WEST
1972 - 1979

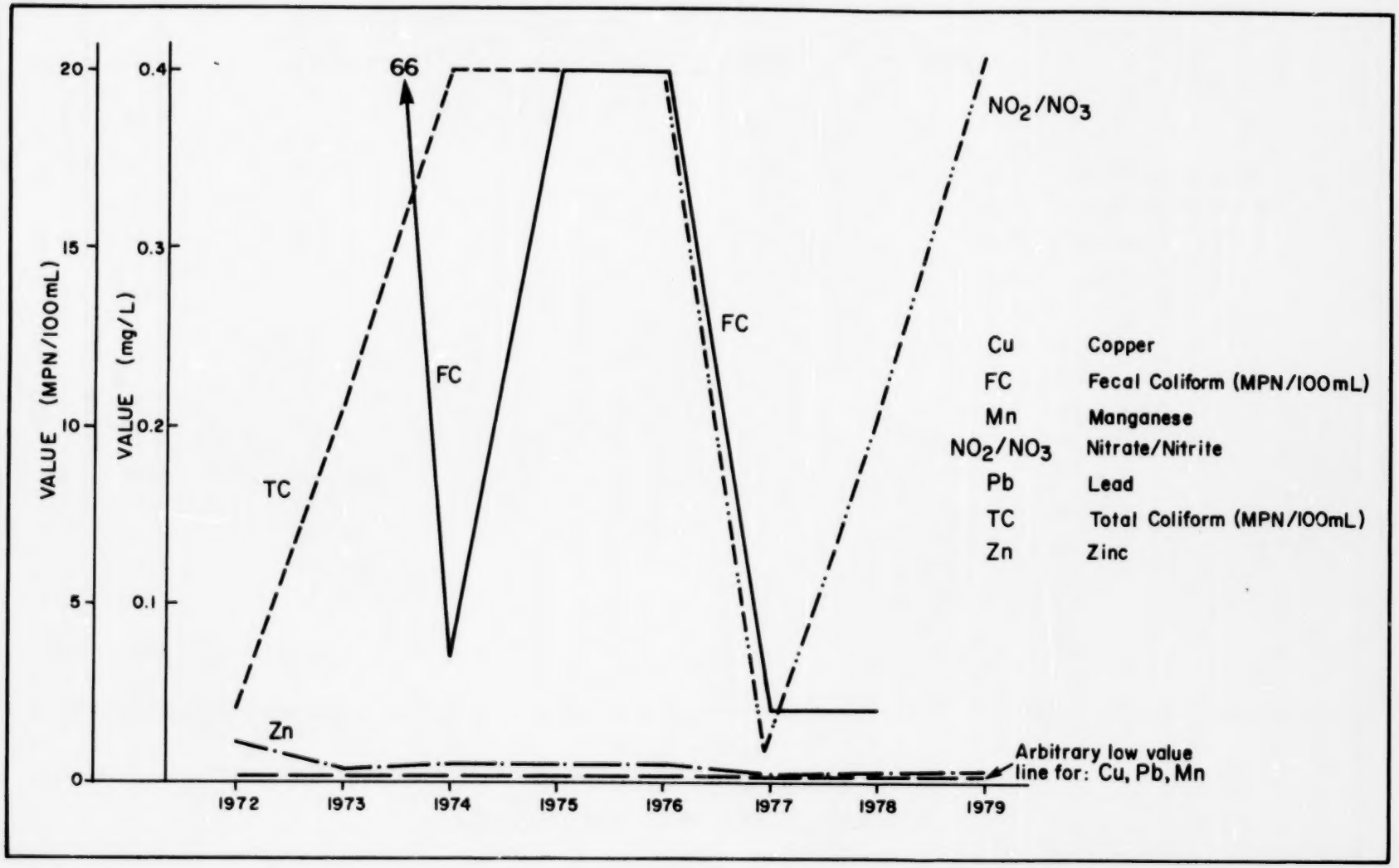


FIGURE 8a
YEARLY MEDIAN VALUE TRENDS
BOUNDARY BAY WEST
1972 - 1979

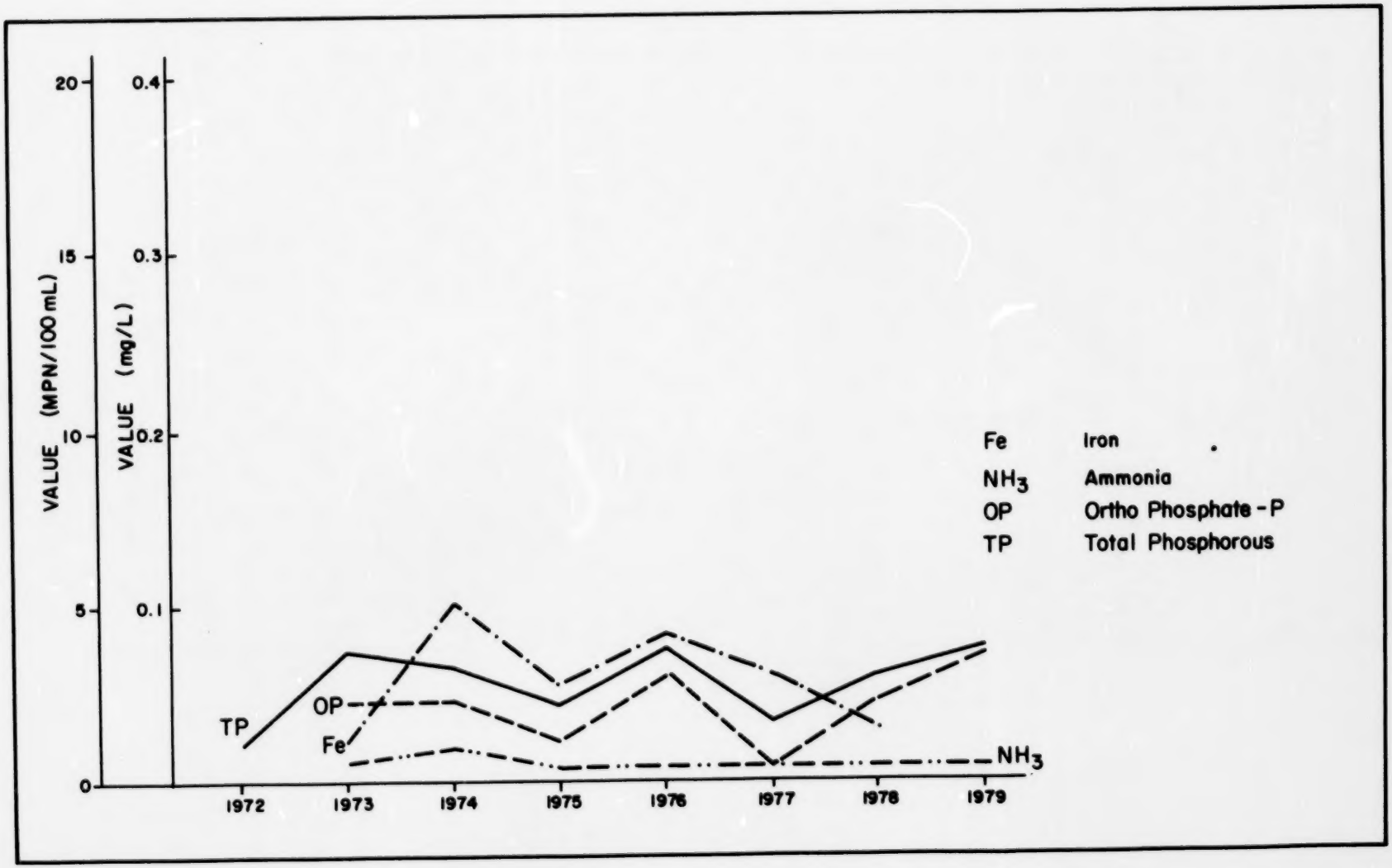


FIGURE 9

OFFICIAL REGIONAL PLAN
GVRD - NOVEMBER 1980

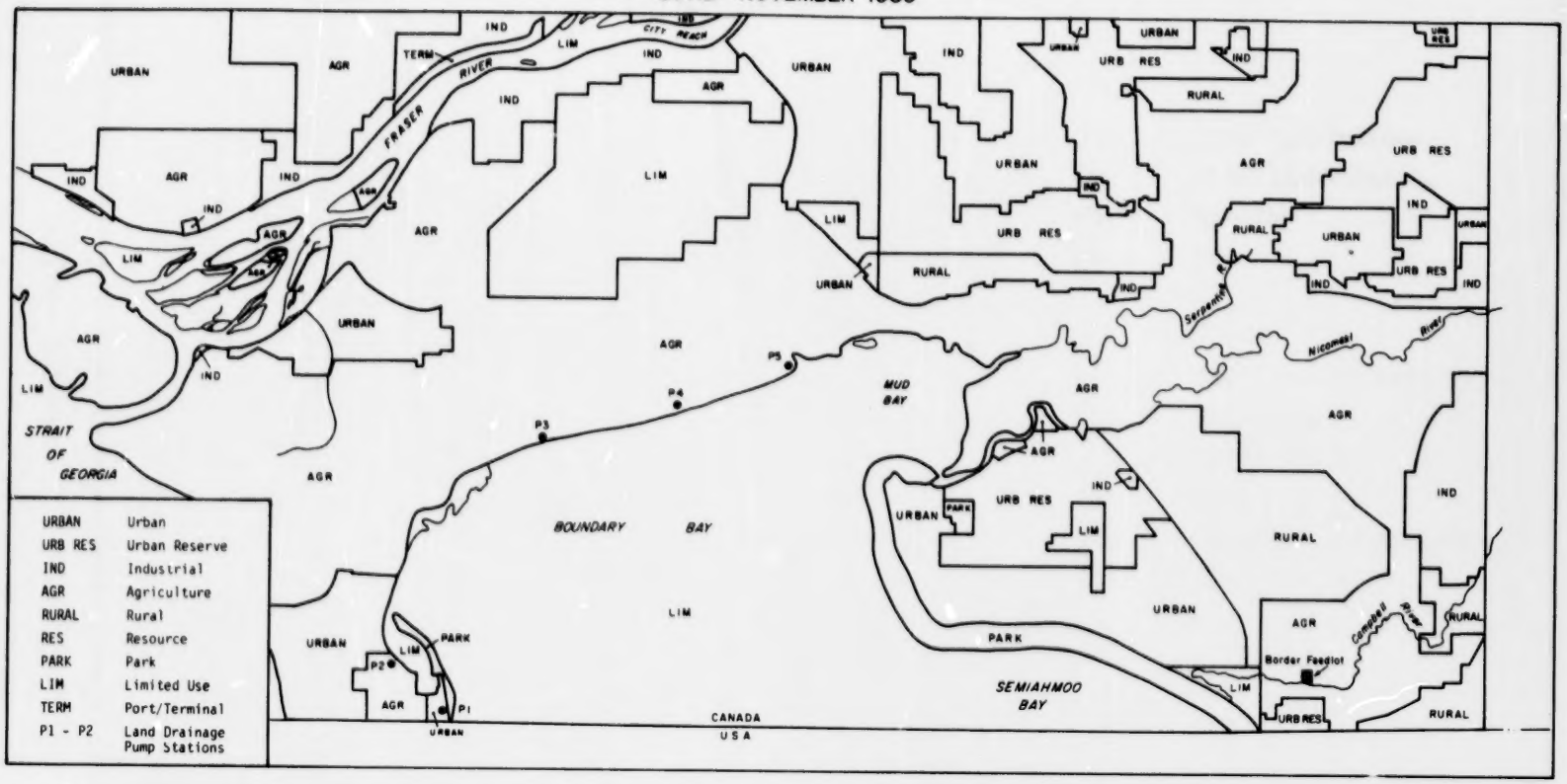


FIGURE 10

INDUSTRIAL EFFLUENTS DISCHARGED IN THE BOUNDARY BAY WATERSHED

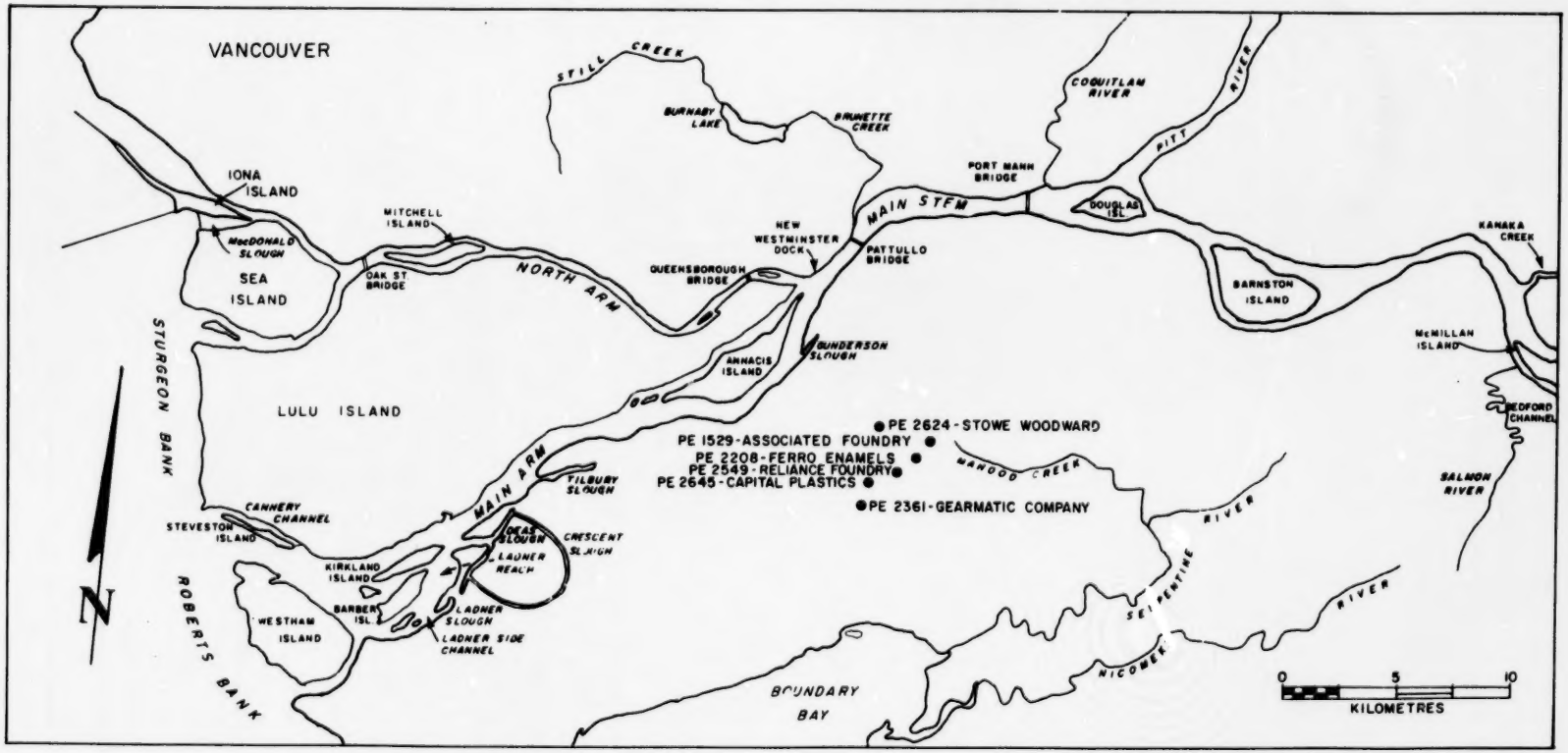


FIGURE 11

BORDER FEEDLOT SITE PLAN

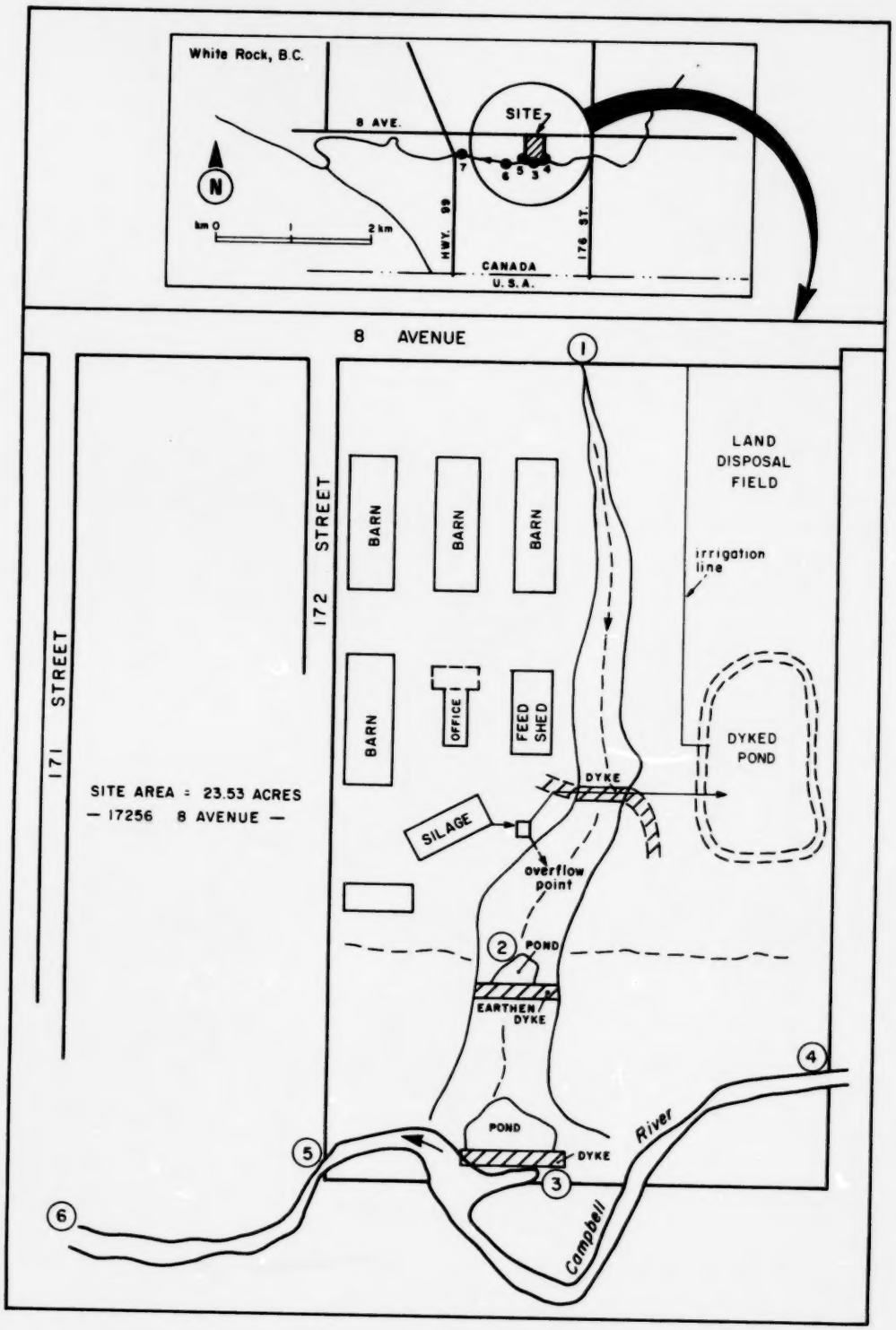


FIGURE 12

LOCATIONS OF LANDFILLS

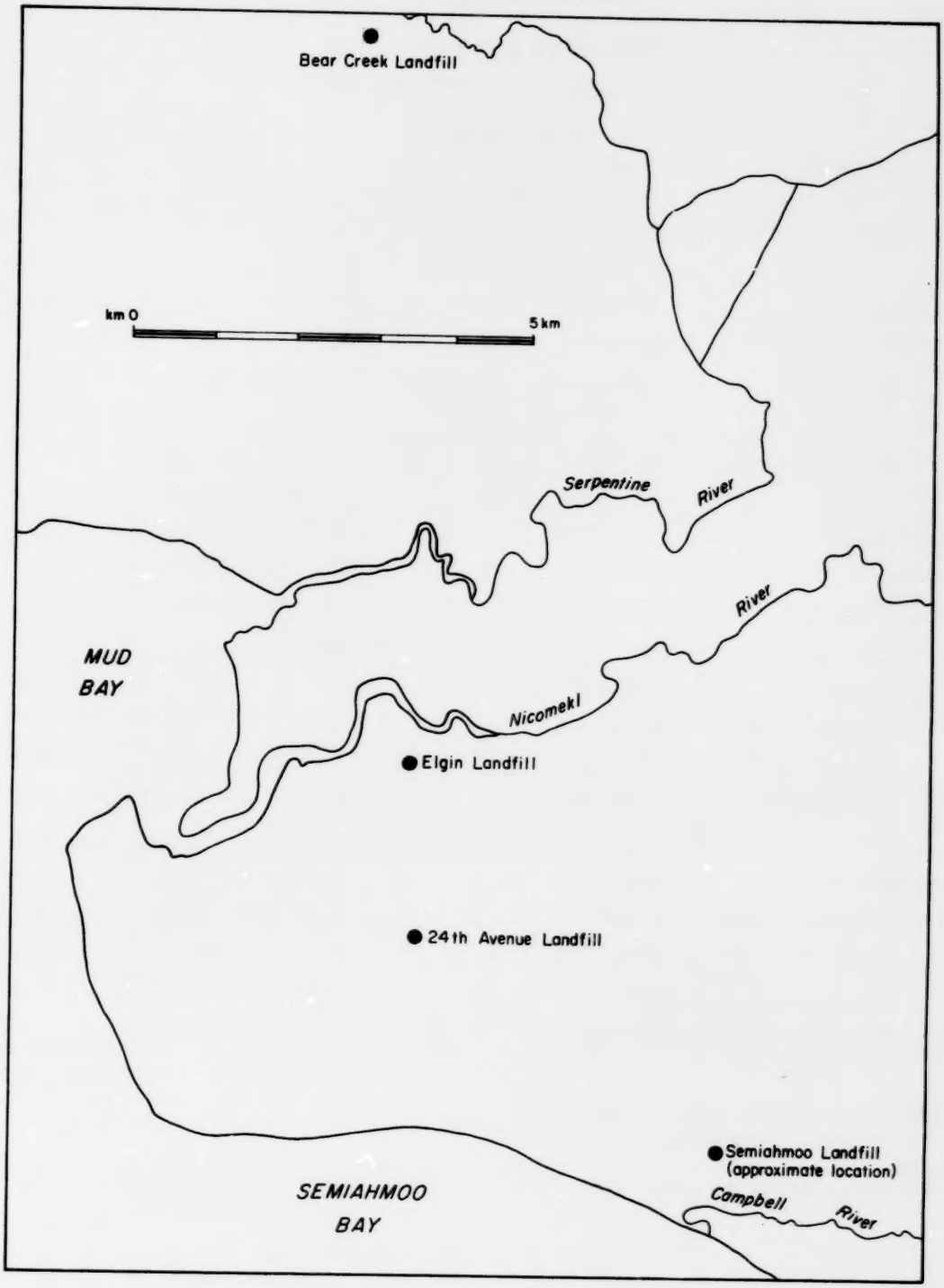


TABLE 1

EFFLUENT DATA SUMMARY

WHITE ROCK SEWAGE TREATMENT PLANT

Parameter	Period of Record	No. of Values	Values*		
			Maximum	Median	Minimum
BOD_5	1972-1976	15	90	37	12
Chlorine Residual	1972-1976	9	2	0.4	0
Coliform - total	1974-1975	2	700 000	-	<20 000
- fecal	1974-1975	3	20 000	20 000	1 300
Copper - total	1973-1974	2	0.11	0.06	0.02
Iron - total	1973-1974	2	1.4	0.85	0.29
Lead - total	1973-1974	2	0.021	0.011	0.001
Nickel - total	1973-1974	2	<0.01	<0.01	<0.01
Nitrogen - total	1975-1976	2	57	52.5	48
(N) - ammonia	1972-1973	2	13	12.5	12
- organic	1973-1976	3	13.2	11	7
- kjeldahl	1972-1976	4	57	50	8.63
- nitrate	1972-1976	7	4.99	1.24	0.03
- nitrite	1972-1976	7	1.76	0.66	0.007
- nitrate/nitrite	1972-1976	2	4.5	2.25	0.05
pH	1972-1976	14	7.6	7.2	6.7
Phosphorus - total	1973-1976	5	9.03	6.45	5.97
(P) - ortho phosphate	1973	2	4.98	4.56	4.14
Solids - total	1972-1975	11	830	418	358
- suspended	1972-1976	14	296	127	5.6
Zinc - total	1973-1974	2	0.13	0.07	0.02

* Values expressed as mg/L except:
(1) Coliform as MPN/100mL
(2) pH

\- No value or cannot be determined.

TABLE 2

DATA SUMMARY

NICOMEKL RIVER AT HWY 99

STATION 1100003

Parameter	Period of Record	No. of Values	Values*		
			Maximum	Median	Minimum
Alkalinity - total	1975-1979	42	246	57.5	17.5
Boron - dissolved	1975-1979	19	1	0.1	<0.1
Cadmium - total	1975	14	<0.0005	<0.0005	<0.0005
Calcium - dissolved	1975-1979	43	238	16.2	6.6
Carbon - organic	1975	14	15	8	4
Chloride	1975-1979	31	4 000	116	16
Coliform - total	1975-1978	8	5 400**	625**	0**
- fecal	1975-1979	15	2 400**	130**	11**
Colour - true	1976-1979	22	150	40	15
Copper - total	1978-1979	9	0.017	0.007	0.002
Dissolved Oxygen	1975-1979	38	22.5	10.3	5.2
Hardness	1976-1979	29	3 780	98.9	28.4
Iron - total	1975-1979	39	4.5	0.9	0.2
Lead - total	1975-1979	22	0.012	0.002	<0.001
Magnesium-dissolved	1975-1979	43	775	11.7	2.9
Manganese - total	1975	15	0.12	0.06	0.03
Mercury - total	1975	13	<0.00005	<0.00005	<0.00005
Nitrogen - ammonia	1975-1979	24	0.221	0.065	<0.01
- nitrate/nitrite	1975-1979	43	3.9	0.88	<0.02
- kjeldahl	1975-1979	43	2	0.89	0.01
pH	1975-1979	48	9.1	7.8	6.35
Phosphorus - total	1975-1979	78	0.312	0.112	0.017
(P) - ortho phosphate	1975-1979	39	0.176	0.053	<0.003
Potassium - dissolved	1975-1979	29	87	4.5	2.1
Salinity	1975-1979	27	13 500	500	0
Sodium - dissolved	1975-1979	29	2 200	65.6	13.6
Solids - total	1975-1979	23	6 542	228	146
- suspended	1975-1979	24	68	13	3
Specific Conductance	1975-1979	76	30 000	538	70
Sulphate	1975-1979	29	583	41.3	16.3
Turbidity	1975-1979	41	46	7.9	1.2
Zinc - total	1975-1979	23	0.11	0.008	<0.005

* Values are expressed as mg/L except:
(1) Coliform as MPN/100 mL
(2) pH
(3) Salinity as parts per thousand
(4) Specific Conductance as µmhos/cm
(5) Turbidity as Jackson Turbidity Units

** Coliform data were generated by Waste Management Branch (station 0300060 which corresponds to this station).

TABLE 3

LISTING OF REPORTED FISH KILLS
TRIBUTARY STREAMS[a]

River	Date	Species	Number	Suspected Cause	Circumstances	Comments
Campbell	July 1964	coho trout	2 000-3 000	Lindane	Disposal of garbage containing flea powder into river.	
	September 1970	coho flounders	200	Insufficient oxygen	Discharge from corn mulch pile.	
	September 1970	coho cutthroat	considerable	Pesticide	Spraying of Peace Portal Golf Course.	Also affected the Serpentine River
	August 1972	trout, salmon stickleback	>1 000	Pentachlorophenol	Chemical sprayed on transmission pole by Tammen Pole Services.	Charged and convicted - 1973
	October 1973	coho	<100	Insufficient oxygen	Discharge from mulch pile.	
	June 1975	sculpin stickleback	No Data	No Data	All effects appeared to be in intertidal area of stream.	
	October 1976	coho, stickleback rainbow, cutthroat starry flounder cottids, others	>1 200	Insufficient oxygen	Silage liquor drained by ditch into creek causing high BOD_5 and low oxygen.	Feed lot charged
Hyland Creek	June 1971	salmon, trout	>100	Excessive pH	Water from concrete batch plant washing facilities entered creek.	
	January 1973	salmon, trout	100-500	Excessive pH	Water from concrete batch plant washing facilities entered creek.	Charges laid
Nicomekl	June 1969	trout, salmon	>1 000	Insufficient oxygen, pesticide	Spraying in area prior to kill.	

[a]Source: Department of Fisheries and Oceans - Canada; Listing of Fish Kills in British Columbia.

TABLE 3 (CONTINUED)

LISTING OF REPORTED FISH KILLS
TRIBUTARY STREAMS[a]

River	Date	Species	Number	Suspected Cause	Circumstances	Comments
Serpentine	October 1958	coho chum	>100 100-500	Fluorusilicic Acid	Effluent from fertilizer and chemical company.	
	September 1970	No Data	No Data	Pesticide	Spraying of Peace Portal Golf Course.	Also affected the Campbell River
	July 1973	fry	No Data	Insufficient oxygen, high temperature	No evidence of pollution found - did find low oxygen and high temperatures in water.	
	August 1975	No Data	No Data	Substance washed into stream following rainfall	Fish, both alive and dead, were observed for over one mile.	
	June 1979	coho fry	>100	-	Some fish lived while others were affected and died.	
	December 1979	carp, adult salmon and fry, cutthroat trout	>100	-		
	October 1980	salmon, carp, bullheads, flounders, shiners	>400	Insufficient oxygen	Unseasonally high air temperatures	
Bear (Mahood) Creek	April 1971	coho, trout	extensive	Insecticide	Leather jacket control and heavy rainfall.	
	July 1972	trout	50	Insufficient oxygen	Sewage line repair work resulted in sewage release.	
	April 1977	coho, steelhead cutthroat, lamprey	>100	Anionic surfactants	Alleged spill from Associated Foundry.	

[a]Source: Department of Fisheries and Oceans - Canada; Listing of Fish Kills in British Columbia.

TABLE 4

UNDISSOCIATED AMMONIA VALUES AT O PARTS PER THOUSAND (P.P.T.) SALINITY

pH	Temp. °C	Percent Un-Ionized Ammonia*	Total Ammonia Concentration mg/L									
			0.025	0.05	0.075	0.1	0.2	0.3	0.4	0.5	1.0	1.5
	0	0.09	-	-	-	-	-	-	-	-	0.001	0.001
7.0	10	0.19	-	-	-	-	-	0.001	0.001	0.001	0.002	0.003
	20	0.39	-	-	-	-	0.001	0.001	0.002	0.002	0.004	0.006
	0	0.28	-	-	-	-	0.001	0.001	0.001	0.001	0.003	0.004
7.5	10	0.58	-	-	-	0.001	0.001	0.002	0.002	0.003	0.006	0.009
	20	1.22	-	-	0.001	0.001	0.002	0.004	0.005	0.006	0.012	0.018
	0	0.87	-	-	<0.001	0.001	0.002	0.003	0.003	0.004	0.009	0.013
8.0	10	1.82	-	0.001	0.001	0.002	0.004	0.005	0.007	0.009	0.018	0.027
	20	3.77	0.001	0.002	0.003	0.004	0.008	0.011	0.015	0.019	0.038	0.057
	0	2.71	<0.001	0.001	0.002	0.003	0.005	0.008	0.011	0.014	0.027	0.041
8.5	10	5.55	0.001	0.003	0.004	0.006	0.011	0.017	0.022	0.028	0.055	0.083
	20	11.02	0.003	0.005	0.008	0.011	0.022	0.033	0.044	0.055	0.110	0.165
	0	8.10	0.002	0.004	0.006	0.008	0.016	0.024	0.032	0.041	0.081	0.121
9.0	10	15.67	0.003	0.007	0.011	0.016	0.031	0.047	0.063	0.078	0.157	0.235
	20	28.10	0.007	0.014	0.021	0.028	0.056	0.084	0.112	0.140	0.281	0.422

- Indicates values <0.001 mg/L.
* Based on equations contained in Clark and Drinnan[16].

NOTE
Dark line delineates approximate value of 0.02 mg/L NH_3 (0.016 mg/L as N).

TABLE 5

UNDISSOCIATED AMMONIA VALUES AT 20 PPT. SALINITY

pH	Temp. °C	Percent Un-ionized Ammonia*	Total Ammonia Concentration mg/L													
			0.1	0.2	0.3	0.4	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
	0	0.08	-	-	-	-	-	0.001	0.002	0.002	0.003	0.004	0.005	0.006	0.006	0.007	0.008
7.0	10	0.16	-	-	-	-	0.001	0.002	0.003	0.005	0.006	0.008	0.009	0.011	0.013	0.014	0.016
	20	0.34	-	-	-	0.001	0.002	0.003	0.007	0.010	0.014	0.017	0.020	0.024	0.027	0.030	0.034
	0	0.24	-	-	-	0.001	0.001	0.002	0.005	0.007	0.010	0.012	0.014	0.017	0.019	0.022	0.024
7.5	10	0.51	-	-	0.001	0.002	0.003	0.005	0.010	0.015	0.020	0.026	0.030	0.036	0.041	0.046	0.051
	20	1.08	0.001	0.002	0.003	0.004	0.005	0.010	0.022	0.032	0.043	0.054	0.065	0.076	0.086	0.097	0.108
	0	0.77	0.001	0.002	0.002	0.003	0.004	0.008	0.015	0.023	0.031	0.039	0.046	0.056	0.062	0.069	0.077
8.0	10	1.61	0.002	0.003	0.005	0.006	0.008	0.016	0.032	0.048	0.064	0.081	0.097	0.113	0.129	0.145	0.161
	20	3.33	0.003	0.007	0.010	0.013	0.017	0.033	0.067	0.100	0.133	0.167	0.200	0.233	0.266	0.300	0.333
	0	2.39	0.002	0.005	0.007	0.010	0.012	0.024	0.048	0.071	0.096	0.120	0.143	0.167	0.191	0.215	0.239
8.5	10	4.91	0.004	0.008	0.013	0.017	0.020	0.042	0.084	0.126	0.168	0.210	0.295	0.344	0.393	0.442	0.419
	20	9.82	0.009	0.019	0.028	0.037	0.046	0.093	0.186	0.278	0.371	0.464	0.589	0.687	0.786	0.884	0.928

- Indicates values <0.001 mg/L.
* Based on equations contained in Clark and Drinnan[16].

NOTE
Dark line delineates approximate value of 0.02 mg/L NH_3 (0.016 mg/L as N).

TABLE 6

CALCULATED UNDISSOCIATED AMMONIA VALUES

NICOMEKL RIVER

1100003

Date	Total Ammonia mg/L	Temperature (°C)	pH	Salinity ppt	Undissociated Ammonia	
					%	mg/L
76/03/23	0.141	5.9	6.6	0	0.05	<0.01
76/03/23	0.154	5.9	6.6	0.23	0.05	<0.01
76/05/26	0.036	13.6	8.4	0.39	5.74	<0.01
76/05/26	0.03	14.5	8.4	1.09	6.09	<0.01
76/07/07	0.01	19.5	8.3	0	7.00	<0.01
76/09/02	0.038	17.9	7.9	0.18	2.59	<0.01
76/11/17	0.124	8	7.3	0	0.32	<0.01
77/01/18	0.216	6.5	6.9	0	0.11	<0.01
77/04/14	0.221	11	7.1	0	0.25	<0.01
77/04/14	0.18	9.5	7.1	0.71	0.22	<0.01
77/06/16	0.01	22.5	8.5	2.95	12.78	<0.01
77/06/16	0.01	22.5	8.3	7.74	8.23	<0.01
77/07/26	0.12	23.75	8.3	0.28	9.36	0.01
77/07/26	0.09	22.2	8.2	0.71	6.79	0.01
78/06/21	0.062	21.5	7.8	0.26	2.69	<0.01
78/06/21	0.067	20.75	7.9	0.33	3.18	<0.01
78/08/16	0.106	19	7.5	0.40	1.13	<0.01
78/11/09	0.189	18	6.8	0	0.21	<0.01
79/07/10	0.05	21.3	8.6	0.54	14.62	0.01
79/08/22	0.01	21.75	9.1	1.61	35.74	<0.01

TABLE 7

UNITED STATES EPA WATER QUALITY CRITERIA[7]

Constituent	Criterion	Remarks
Boron	0.75 mg/L	Long term irrigation of sensitive crops.
Cadmium	0.4 µg/L	Aquatic Life, Soft Water, Salmonid Fishes.
Chromium	0.1 mg/L	
Copper	0.02 mg/L*	0.1 of the 96-hour LC_{50} Rainbow trout (no age)-0.4 mg/L Chinook Salmon (no age)-0.178 mg/L therefore (0.1) (0.178) = 0.0178 mg/L, i.e. 0.02 mg/L
Dissolved Oxygen	5.0 mg/L	
Iron	1.0 mg/L	
Lead	0.005 mg/L*	0.01 of the 96-hour LC_{50} Rainbow trout - 1.38 mg/L Free Pb Coho Salmon - 0.52 mg/L Pb therefore (0.01) (0.52) = 0.0052 mg/L, i.e. 0.005 mg/L
Manganese	0.1 mg/L	For protection of consumers of marine mullusks.
Mercury	0.05 µg/L	
Nickel	0.05 mg/L*	0.01 of the 96-hour LC_{50} Range for four species of fish in soft water quoted as being from 4.6 mg/L to 9.8 mg/L therefore (0.01) (4.6) = 0.046 mg/L, i.e. 0.05 mg/L
Zinc	0.001 mg/L*	0.01 of the 96-hour LC_{50} Rainbow trout (7 grams) - 0.10 mg/L Zn Chinook Salmon (1 month old) - 0.103 mg/L therefore (0.01) (0.1) = 0.001 mg/L

* Interpreted by Authors.

NOTE
As listed for freshwater aquatic life except where interpreted by authors.

TABLE 8

DATA SUMMARY

SERPENTINE RIVER AT HWY 99

STATION 1100034

Parameter	Period of Record	No. of Values	Values*		
			Maximum	Median	Minimum
Alkalinity - total	1975-1979	38	203	49.6	12.4
Boron - dissolved	1975-1979	15	1	0.1	<0.1
Cadmium - total	1975	11	<0.0005	<0.0005	<0.0005
Calcium - dissolved	1975-1979	39	305	16	6
Carbon - organic	1975	11	13	10	8
Chloride	1975-1979	27	3 900	123	8.4
Coliform - total	1975-1978	7	16 000**	490**	140**
- fecal	1975-1979	14	16 000**	100**	12**
Colour - true	1976-1979	22	150	60	15
Copper - total	1978-1979	8	0.016	0.007	0.002
Dissolved Oxygen	1975-1979	33	18.3	10.1	2.5
Hardness	1976-1979	28	4 380	121	24
Iron - total	1975-1979	35	4.9	1.7	0.4
Lead - total	1975-1979	20	0.015	0.005	<0.001
Magnesium-dissolved	1975-1979	39	880	18.1	2.2
Manganese - total	1975-1976	12	0.24	0.11	0.05
Mercury - total	1975	11	0.00007	0.00005	<0.00005
Nitrogen - ammonia	1976-1979	22	0.25	0.098	<0.01
- nitrate/nitrite	1975-1979	39	2.65	0.56	<0.02
- kjeldahl	1975-1979	38	2	1	0.44
pH	1975-1979	47	8.75	7.3	6.2
Phosphorus - total	1975-1979	68	0.283	0.098	0.017
(P) - ortho phosphate	1975-1979	34	0.08	0.039	0.007
Potassium	1975-1979	25	280	4	1.7
Salinity	1975-1979	24	13 600	950	0
Sodium - dissolved	1975-1979	25	7 750	102	7.4
Solids - total	1976-1979	17	27 700	528	142
- suspended	1976-1979	17	93	30	16
Specific Conductance	1975-1979	68	38 700	729	8.9
Sulphate	1975-1979	25	1 811	40.1	14.5
Turbidity	1976-1979	39	72	15	5.9
Zinc - total	1975-1979	20	0.11	0.012	<0.005

* Values are expressed as mg/L except:
(1) Colour in relative units
(2) Coliform as MPN/100 mL
(3) pH
(4) Specific Conductance as µmhos/cm
(5) Turbidity as Jackson Turbidity Units

** Coliform data were generated by Waste Management Branch (station 0300057 which corresponds to this station).

TABLE 9

CALCULATED UNDISSOCIATED AMMONIA VALUES

SERPENTINE RIVER

1100034

Date	Total Ammonia mg/L	Temperature (°C)	pH	Salinity ppt	Undissociated Ammonia	
					%	mg/L
76/03/24	0.177	5	6.5	0.34	0.04	<0.01
76/03/24	0.183	5	6.5	0.18	0.04	<0.01
76/05/27	0.029	14	7.0	0	0.25	<0.01
76/07/06	0.02	22	7.9	0.71	3.47	<0.01
76/07/06	0.05	20	7.6	2.95	1.51	<0.01
76/09/01	0.02	17.7	7.9	0.82	2.54	<0.01
76/11/18	0.174	8.6	6.7	0	0.08	<0.01
76/11/18	0.191	8.7	6.7	0.82	0.08	<0.01
77/04/13	0.21	9	7.1	1.15	0.22	<0.01
77/04/13	0.2	8.6	7.0	2.09	0.16	<0.01
77/07/27	0.03	25.5	8.3	0.44	10.51	<0.01
78/06/20	0.212	21	7.2	0.14	0.66	<0.01
78/08/16	0.11	18.1	7.2	0.02	0.54	<0.01
78/11/08	0.145	9	6.7	0	0.09	<0.01
79/07/11	0.25	20.2	8	0.23	3.82	0.01
79/08/22	0.03	20.75	7.9	20.3	2.81	<0.01

TABLE 10

DATA SUMMARY

CAMPBELL RIVER AT 176TH STREET

STATION 0300065

Parameter	Period of Record	No. of Values	Values*		
			Maximum	Median	Minimum
Alkalinity - total	1972-1979	26	64.9	40.1	23.7
Arsenic - total	1975	2	<0.005	<0.005	<0.005
Boron - dissolved	1972	3	<0.2	<0.1	<0.1
Cadmium - total	1974	1	<0.0005	-	-
Calcium - dissolved	1972-1979	26	13.6	10.5	6
Chloride	1972-1979	26	14.4	9.8	3.9
Chromium - total	1972-1978	14	0.013	<0.005	<0.005
Coliform - total	1972-1979	19	9 180	1 100	220
- fecal	1973-1979	21	3 500	790	49
Colour - true	1972-1973	5	50	30	20
Copper - total	1972-1979	21	0.023	<0.001	<0.001
Dissolved Oxygen	1972-1979	25	13.5	10.3	8.1
Hardness	1972-1979	26	56.8	42.7	25.3
Iron - total	1972-1979	22	2.1	0.8	0.4
Lead - total	1972-1979	22	0.004	0.001	<0.001
Magnesium-dissolved	1972-1979	25	5.6	4	2.5
Manganese - total	1972-1979	21	0.2	0.05	0.02
Nickel - total	1972-1978	19	0.01	0.01	<0.01
Nitrogen - ammonia	1973-1979	23	0.194	0.059	<0.01
- nitrate/nitrite	1977-1979	9	1.54	0.98	0.78
- kjeldahl	1972-1979	20	1	0.43	0.16
pH	1972-1979	38	8	7.4	6.7
Phosphorus - total	1972-1979	32	0.202	0.058	0.032
(P) - ortho phosphate	1973-1979	23	0.101	0.028	0.013
Potassium	1972-1979	21	3.4	1.9	1
Sodium - dissolved	1972-1979	19	16	9.6	5.1
Solids - total	1972-1979	9	180	108	68
- suspended	1974-1979	18	36	11	3
Specific Conductance	1972-1979	40	980	144	80
Sulphate	1972-1979	21	15.5	7.8	<5
Turbidity	1972-1975	6	34	6.5	4.2
Zinc - total	1972-1978	19	0.038	0.005	<0.005

* Values are expressed as mg/L except:
(1) Colour in relative units
(2) Coliform as MPN/100 mL
(3) pH
(4) Specific Conductance as µmhos/cm
(5) Turbidity as Jackson Turbidity Units

\- No value.

TABLE 11

DATA SUMMARY

IMPACT OF BORDER FEEDLOT ON ADJACENT CREEK

Parameter	Values*			
	Sampling Site**			
	1 (Upstream)		2 (Downstream)	
	73/10/31	73/12/04	73/10/31	73/12/04
Carbon - total organic	18	29	4 714	70
- total inorganic	-	14	-	26
Nitrogen - ammonia	0.06	0.10	-	1
- nitrate	0.08	1.25	1.04	2.8
- nitrite	0.008	0.009	0.014	0.589
- organic	1	2	24	4
Oxygen - BOD_5	<10	<10	>6 100	95
pH	6.6	6.6	4.2	6.5
Phosphorus - total	0.162	0.227	21.3	0.814
(P) - ortho phosphate	0.059	0.126	17.9	0.404
Solids - total	282	384	6 786	500
- total fixed	226	270	1 662	332
Specific Conductance	377	550	2 650	670
Tannin and Lignin	1.5	2.7	190	3.8

* Values are expressed as mg/L except:
(1) pH
(2) Specific Conductance as µmhos/cm.

** Sampling sites referred to in Figure 11.

TABLE 12

DATA SUMMARY

IMPACT OF BORDER FEEDLOT ON CAMPBELL RIVER

Parameter	Values*					
	Sampling Site**					
	4 (Upstream)			5 (Downstream)		
	73/10/30	73/11/08	73/12/04	73/10/31	73/11/08	73/12/04
Carbon - total organic	8	16	12	8	30	10
- total inorganic	11	60	3	-	60	4
Nitrogen - ammonia	0.08	0.27	0.12	0.13	0.41	0.13
- nitrate	1.12	1.35	1.58	1.11	1.36	1.59
- nitrite	0.044	0.028	0.009	0.050	0.028	0.009
- organic	0.64	1	0.67	1	1	0.68
Oxygen - BOD_5	<10	<10	<10	10	27	<10
pH	7.3	7.4	1.0	7.0	7.1	7.0
Phosphorus - total	0.118	0.232	0.085	0.140	0.235	0.087
(P) - ortho phosphate	0.072	0.135	0.044	0.030	0.102	0.046
Solids - total	158	-	106	182	-	100
- total fixed	118	-	58	126	-	62
Specific Conductance	203	212	114	206	217	116
Tannin and Lignin	0.8	1.3	1	0.8	1.3	1

* Values are expressed as mg/L except:
(1) pH
(2) Specific Conductance in µmhos/cm.

** Sampling sites referred to in Figure 11.

TABLE 13

FLOW DATA SUMMARY[6]

CAMPBELL RIVER NEAR WHITE ROCK

STATION NO. 08MH059

Monthly and Annual Mean Discharges in Cubic Metres Per Second													
Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean
1961	-	-	-	-	0.92	0.29	0.20	0.13	0.15	0.32	0.88	1.92	-
1962	1.85	1.00	1.03	0.84	0.61	0.23	0.10	0.14	0.10	0.28	1.01	1.38	0.71
1963	1.65	1.85	1.04	1.29	0.71	0.24	0.29	0.22	0.14	0.22	2.34	3.99	1.16
1964	2.97	1.14	2.16	0.99	0.48	0.22	0.18	0.06	0.23	-	-	-	-
Mean	2.16	1.33	1.41	1.04	0.68	0.25	0.20	0.14	0.16	0.27	1.41	2.43	0.94

Latitude: 49^{o} 00' 57" N

Longitude: 122^{o} 43' 22" W

Drainage Area: 63.71 square kilometres

TABLE 14

DATA SUMMARY

BOUNDARY BAY EAST

STATION 0300071

Parameter	Period of Record	No. of Values	Values*		
			Maximum	Median	Minimum
Alkalinity - total	1973-1979	52	114	104	90
Arsenic - total	1975	4	0.005	0.005	<0.005
Boron - dissolved	1978	2	6	5	4
Cadmium - total	1973-1975	24	0.0005	0.0005	<0.0001
Calcium - dissolved	1974-1978	8	361	333	292
Chloride	1974-1976	4	16 300	15 300	13 900
Chromium - total	1973-1979	47	0.02	0.006	<0.005
Coliform - total	1973-1976	17	1 700+	20	<2+
- fecal	1973-1978	23	790++	5	<2++
Colour - true	1973-1977	37	10	5	<5
Copper - total	1973-1979	47	0.007	0.001	<0.001
Dissolved Oxygen	1973-1978	44	14	8.8	6.3
Hardness	1974-1978	8	5 590	5 395	4 541
Iron - total	1973-1979	50	0.8	0.055	<0.005
Lead - total	1973-1978	40	0.007	0.001	<0.001
Magnesium-dissolved	1974-1979	35	1 170	1 065	850
Manganese - total	1974-1979	39	0.015	0.005	0.003
Mercury - total	1973-1979	10	0.00006	<0.00005	<0.00005
Molybdenum - total	1975-1976	12	0.0099	0.00885	0.0062
Nickel - total	1973-1979	42	<0.01	<0.01	<0.01
Nitrogen - ammonia	1973-1979	50	0.07	0.01	<0.01
- nitrate/nitrite	1976-1979	15	0.4	0.35	<0.02
- kjeldahl	1974-1979	32	0.34	0.065	<0.01
pH	1973-1979	74	8.6	8	7.4
Phosphorus - total	1973-1979	55	0.129	0.068	0.022
(P) - ortho phosphate	1973-1979	48	0.088	0.047	<0.003
Potassium - dissolved	1974	2	280	279	278
Solids - total	1978-1979	8	33 700	32 350	31 900
- suspended	1973-1979	52	31	5	1.4
Specific Conductance	1973-1979	75	46 700	41 400	>8 000
Turbidity	1973-1979	41	8.4	1.4	0.4
Zinc - total	1973-1979	43	0.05	<0.005	<0.005

* All values are expressed as mg/L except:
(1) Colour in relative units
(2) Coliform as MPN/100 mL
(3) pH
(4) Specific Conductance as µmhos/cm
(5) Turbidity as Jackson Turbidity Units

\+ 10th percentile: 2
90th percentile: 403

++ 10th percentile: 2
90th percentile: 81

TABLE 15

DATA SUMMARY

BOUNDARY BAY WEST

STATION 0300070

Parameter	Period of Record	No. of Values	Values*		
			Maximum	Median	Minimum
Alkalinity - total	1972-1979	61	113	104	78.5
Arsenic - total	1975	4	<0.005	<0.005	<0.005
Boron - dissolved	1972-1978	8	3.3	3	2
Cadmium - total	1973-1975	24	0.0005	0.0005	<0.0001
Calcium - dissolved	1972-1978	16	351	329	264
Chloride	1972-1979	10	16 400	14 100	7 750
Chromium - total	1973-1979	53	0.022	<0.005	<0.005
Coliform - total	1972-1976	20	240+	20	<2+
- fecal	1972-1979	26	130++	5	<2++
Colour - true	1972-1979	45	15	5	<5
Copper - total	1972-1979	55	0.04	0.002	<0.001
Dissolved Oxygen	1972-1979	55	12.1	9	5.8
Hardness	1974-1978	12	5 600	5 324	4 409
Iron - total	1972-1979	54	0.8	0.056	<0.005
Lead - total	1972-1978	49	0.032	0.001	<0.001
Magnesium-dissolved	1974-1979	40	1 200	1 080	815
Manganese - total	1972-1979	47	0.016	0.005	0.002
Mercury - total	1973-1979	13	0.00025	0.00006	<0.00005
Molybdenum - total	1975-1976	14	0.0116	0.0089	<0.0005
Nickel - total	1972-1979	55	0.01	<0.01	<0.01
Nitrogen - ammonia	1972-1979	57	0.09	<0.01	<0.01
- nitrate/nitrite	1976-1979	15	0.42	0.26	<0.02
- kjeldahl	1972-1979	41	0.33	0.03	<0.01
pH	1972-1979	91	8.5	8	7.2
Phosphorus - total	1972-1979	64	0.104	0.065	0.009
(P) - ortho phosphate	1973-1979	51	0.077	0.042	<0.003
Potassium - dissolved	1972-1979	5	313	280	225
Sodium - dissolved	1972-1979	4	8 125	6 700	5 688
Solids - total	1972-1979	12	42 430	32 450	29 726
- suspended	1972-1979	61	29	5	1.1
Specific Conductance	1972-1979	89	47 800	41 000	>800
Sulphate	1972	4	2 200	1 740	1 700
Turbidity	1972-1979	51	6.2	1.3	0.4
Zinc - total	1972-1979	55	0.13	<0.005	<0.005

* All values are expressed as mg/L except:
(1) Colour in relative units
(2) Coliform as MPN/100 mL
(3) pH
(4) Specific Conductance as µmhos/cm
(5) Turbidity as Jackson Turbidity Units

\+ 10th percentile: 2
90th percentile: 212

++ 10th percentile: 2
90th percentile: 52

TABLE 16

DATA SUMMARY

BOUNDARY BAY

"SHORE" BACTERIOLOGICAL QUALITY

1972-1979

General Site Description	Site Number	COLIFORM MPN/100 mL								COMMENTS
		No. of Values	TOTAL			No. of Values	FECAL			
			Maximum	Median	Minimum		Maximum	Median	Minimum	
Boundary	316	166	4 300	40	<30	188	2 300	30	<3	Sampled by GVRD and Ministry of Health. EPS data reported elsewhere[2] [3]
	317	164	24 000	40	<30	140	4 300	30	<30	
	318	208	2 400 000	90	<30	172	2 400 000	40	<30	
Beach Grove	313	154	240 000	150	<30	132	240 000	40	<30	Sampled by GVRD. EPS data reported elsewhere[2] [3]
	314	139	46 000	150	<30	117	4 300	40	<30	
	315	173	240 000	90	<30	149	7 500	40	<30	
Crescent Beach	357	-	-	-	-	58	>2 400	23	<3	Sampled by Ministry of Health. EPS data reported elsewhere[2] [3]
	379	-	-	-	-	58	>2 400	23	<3	
White Rock	378	-	-	-	-	58	1 100	43	4	Sampled by Ministry of Health. EPS data reported elsewhere[2] [3]
	377	-	-	-	-	57	>2 400	43	4	
	381	-	-	-	-	14	1 100	93	15	

TABLE 17

MARINE WATER QUALITY CRITERIA[8]

Constituent	Criterion	Source	Remarks
Arsenic	0.01 mg/L	WQC 1972	(a)
	0.05 mg/L	WQC 1972	(b)
Cadmium	0.0002 mg/L	WQC 1972	(a)
	0.01 mg/L	WQC 1972	(b)
	0.005 mg/L	unlisted	Criterion for protection of aquatic life
Chromium	0.05 mg/L	WQC 1972	(a)
	0.10 mg/L	WQC 1972	(b)
Colour	50 TCU	B.C. Health	Standard for shellfish waters.
Copper	0.01 mg/L	WQC 1972	(a)
	0.05 mg/L	WQC 1972	(b)
Dissolved Oxygen	4 mg/L	WQC 1972	Values below 4 mg/L can be expected to impact marine biota
Iron	0.05 mg/L	WQC 1972	(a)
	0.30 mg/L	WQC 1972, WM	(b)
Lead	0.01 mg/L	WQC 1972	(a)
	0.05 mg/L	WQC 1972	(b)
Manganese	0.02 mg/L	WQC 1972	(a)
	0.10 mg/L	WQC 1972, QCW	(b), for protection of consumers of marine mollusks
Mercury	0.10 µg/L	WQC 1972	(b)
Nickel	0.002 mg/L	WQC 1972	(a)
	0.10 mg/L	WQC 1972	(b)
Nitrogen - Ammonia	0.01 mg/L	WQC 1972	(a)
(undissociated)	0.40 mg/L	WQC 1972	(b)
pH (minima)	6.5	WQC 1972, QCW	Criterion for marine aquatic life
(maxima)	8.5	WQC 1972, QCW	Criterion for marine aquatic life
Phosphorus - total	0.05 mg/L	WQC 1972	0.05 mg/L P is excessive in marine environment (as available nutrient)
Turbidity	25 JTU	B.C. Health	Shellfish Growth and Propagation
Zinc	0.02 mg/L	WQC 1972	(a)
	0.10 mg/L	WQC 1972	(b)

Source Identification:

QCW (reference #7)
B.C. Health - Recommended Water Quality Standards - 1969.
WM - Water Management, Ontario Ministry of Environment - 1978.
WQC 1972 - United States EPA Water Quality Criteria -1972.

Remarks:

(a) Minimal Risk to Marine Environment.
(b) A Hazard to Marine Environment.